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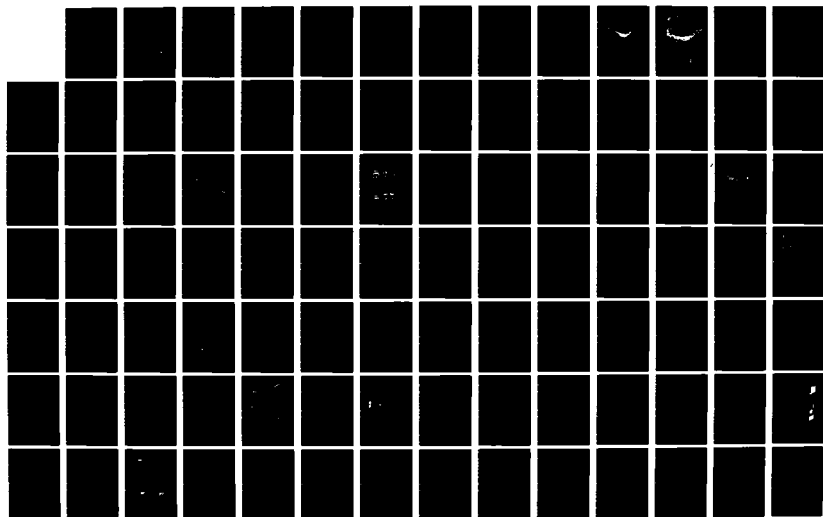
INTEGRATION ENGINEERING HANDBOOK FOR ENVIRONMENTAL
CONTROL(U) RADIAN INC ALEXANDRIA VA P A JORDAN
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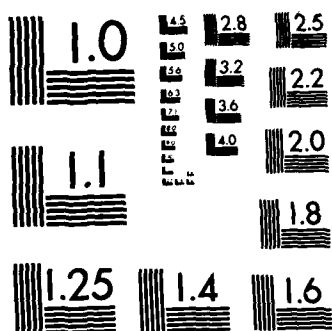
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Report No. 83-5-525-0015

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INTEGRATION ENGINEERING HANDBOOK FOR ENVIRONMENTAL CONTROL

RADIAN INC.
20-30 South Quaker Lane
Alexandria, VA 22314-4585

2 May 1983

Final

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Prepared for
SHELTER MANAGEMENT OFFICE
Headquarters, Electronics Systems Division (AFSC)
Hanscom Air Force Base, MA 01731

Through
ELECTROMECHANICAL DIVISION, ENGINEER SERVICE SUPPORT LABORATORY
U.S. Army Mobility Equipment Research and Development Command
Fort Belvoir, VA 22060

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 83-5-525-0015	2. GOVT ACCESSION NO. AD-8128632	3. RECIPIENT'S CATALOG NUMBER
TITLE (and Subtitle) Integration Engineering Handbook for Environmental Control		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) P.A. Jordan, III RADIAN INC.		8. CONTRACT OR GRANT NUMBER(s) DAAK70-81-P-0120
9. PERFORMING ORGANIZATION NAME AND ADDRESS RADIAN INC. 20-30 South Quaker Lane Alexandria, VA 22314-4585		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element 64708F Project No. 2674
11. CONTROLLING OFFICE NAME AND ADDRESS Shelter Management Office Headquarters, Electronics Systems Division (AFSC) Hanscom Air Force Base, MA 01731		12. REPORT DATE 2 May 1983
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electromechanical Div., Engineer Service Spt Lab., U.S. Army Mobility Equipment Research and Development Command Fort Belvoir, VA 22060		13. NUMBER OF PAGES 143
		15. SECURITY CLASS. (of this report) Unclassified
16. DISTRIBUTION STATEMENT (of this Report) Distribution of this document is unlimited.		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE Not applicable
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Distribution of the abstract is unlimited.		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Air conditioning, Blast and thermal effects, Chemical and biological effects, Cooling and heating load, Environmental control unit mounting methods, Electro- magnetic pulse (EMP) effects on ECU, Environmental control unit (ECU), Heating, Mobile tactical shelters, System integration.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This handbook offers those who are not heating and air conditioning engineers guidance and procedures for meeting uncomplicated cooling and heating require- ments in standard, mobile, military shelters. The handbook addresses the selec- tion and mounting of environmental control units, introduction of conditioned air into the shelter and its distribution, chemical and biological warfare equipment application, and steps that might help the environmental control system to survive in a nuclear environment. The handbook is intended as a simplified guide; it recognizes that expert help from technical documents and qualified engineers may be required in complicated situations.		

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SECTION I - INTRODUCTION

I-1. Introduction

This handbook offers those of you who are not heating and air conditioning engineers, guidance and procedures for meeting uncomplicated cooling and heating requirements in standard, small, military shelters.

I-2. Scope

The handbook addresses:

- The selection and mounting of standard military environmental control units (ECU)¹.
- Introduction of conditioned air into the shelter and its distribution.
- Chemical and biological (CB) warfare protective equipment and its use with the ECU.
- Steps that might help the ECU to survive and function in a nuclear-CB (NBC) environment.

I-3. General Parameters

The extent and boundaries of the handbook are defined in large part by the shelters considered, the ECU's available and the climatic extremes of potential operational areas.

• Shelters Considered. The shelters which are considered are taken from the Standard Family of Tactical Shelters (Reference 25 of Appendix I-2). The total list was culled to leave a fully representative range of size and structural types, all of which should be readily procurable. You will find these tabulated at Figure I-1.

• ECU's Considered. Only standard military compact ECU's and four Navy adaptations of commercial models are considered for the applications of this handbook. The military units are all included in Military Specification MIL-A-52767B (Reference 27) and Military Standard 1408A (Reference 32); the Navy units are in Navy Technical Manual NAVAIR 19-60-83 (Reference 35). Descriptive data extracted from MIL-A-52767B and NAVAIR 19-60-83 are tabulated in Figure I-2.

• Climatic Conditions and Categories. Figure I-3 tabulates the world temperatures and humidities by the climatic categories agreed to in QSTAG 360 (Reference 15). The locations of the world in which these conditions are found are shown on Figure I-4. These data are necessary in determining the required ECU capacity. You will note that in regions where heat is the principal consideration the highest temperatures are given and the lowest temperatures where cold is the main consideration.

¹See definition in Appendix I-1.

I-4. Use of Handbook

• This is a guide. You may find that it is all you need in most situations. However, you may occasionally encounter more complicated problems which will require professional assistance or reference to appropriate technical publications. The handbook attempts to highlight where these instances might arise. When you do need help, one of the first places to look is Reference 4, Appendix I-2.

• The handbook is organized so that back-up information is included in appendices at the rear. For speed of reference, each appendix has been numbered to correspond with the section it supports; for example, the II-series of appendices supports Section II. Appendix I-1 is an explanation and illustration of terms. You should find it helpful to become aware of these terms before beginning the use of this handbook.

I-5. Coordinated Planning

• Your job will be much easier if you can approach the environmental control aspects in conjunction with the planning for all other equipment to be installed in a shelter. If you can treat these as a system, a better product should result. Two examples of areas in which coordinated planning would pay dividends are the utilization of shelter space that the ECU and its ducting must share with operational equipment and the compatibility of power requirements for the ECU and other equipment in terms of voltage, phase, and frequency.

Designation	Service Sponsor	Nominal Outside Dimensions (HxWxL) (ft)	Inside Dimensions (HxWxL) (ft/in.)
<u>Nonexpandable</u>			
S250	Army	6 x 6½ x 7	H: 5'4" in aisle : 3'10" at side wall W: 6'3" at top : 3'8" at floor L: 6'6"
S280	Army	7½ x 7½ x 12	6'5" x 6'10" x 11'6"
ISO GP	Army	8 x 8 x 20	7'1" x 7'7" x 19'1"
MF ISO ¹	Navy	8 x 8 x 20	7'18" x 7'6" x 19'4"
<u>Expandable</u>			
S-530 A/G	Air Force	7½ x 7½ x 12 (unexpanded)	Unexpanded: 6'9" x 6'7" x 11'5" Expanded: 6'9" x 19'9" x 11'5" ²
ISO, one side expandable	Army	8 x 8 x 20 (Unexpanded)	Unexpanded: 7'1" x 6'5" x 19'1" Expanded: 7'1" x 14'6" x 18'4"
ISO, two sides expandable	Army	8 x 8 x 20 (Unexpanded)	Unexpanded: 7'16" x 6'0" x 19'1" Expanded: 7'1" x 21'6" x 18'4"

¹The Navy MF ISO has three configurations:

1. Single unit basic mobile facility.
2. Side joining units A and B which join into a double unit.
3. Integration unit to which up to six single basic units can be attached, end on: one to each end and two to each side.

All MF ISO units have the same dimensions and the same thermal characteristics.

²Two shelters joined.

Figure I-1. *STANDARD SMALL MILITARY SHELTERS
CONSIDERED IN THIS HANDBOOK*

Nominal Capacity (Btuh)	Rating (Btuh)		Dimensions H x W x L (Inches)	Weight (lb)	Power										Consumption (KW)	
					Requirement											
					Voltage			Phase		Freq. (Hz)		Wires				
	Cooling ²	Heating			115	208	230	1	3	50/60	400	3	4	50/60 Hz	400 Hz	
Horizontal Configuration (Army)																
9,000	10,000	7,000	16 $\frac{1}{8}$ x 23 $\frac{7}{8}$ x 26 $\frac{1}{2}$	200	X			X		X		X		3.2		
						X		X		X		X		3.2		
18,000	18,500	14,300	20 x 30 x 28	290		X		X		X		X		3.0		3.1
						X		X		X		X		6.5		
36,000	41,000	31,200	29 $\frac{1}{8}$ x 38 $\frac{1}{16}$ x 35 $\frac{3}{16}$	435		X				X		X		6.5		6.5
						X				X		X		13.5		13.5
60,000	62,000	45,000	27 $\frac{1}{8}$ x 44 $\frac{1}{8}$ x 41 $\frac{3}{4}$	600		X				X		X		14.0		18.0
						X				X		X		18.0		
Vertical Configuration (Army)																
6,000	6,300	4,500	28 $\frac{1}{4}$ x 17 x 17	180	X			X		X		X		2.2		2.6
9,000	9,350	6,000	32 x 17 x 17	200	X			X		X		X		3.6		
							X		X		X		3.4			
18,000	19,300	12,000	45 $\frac{5}{8}$ x 17 $\frac{3}{4}$ x 20	270		X				X		X		3.4		3.6
						X				X		X		5.0		5.7
36,000	37,800	28,600	55 $\frac{1}{4}$ x 30 $\frac{5}{8}$ x 21 $\frac{1}{2}$	460		X				X		X		8.5		10.5
						X				X		X		15.5		18.6
60,000	60,000	47,000	65 $\frac{13}{16}$ x 34 $\frac{5}{8}$ x 23 $\frac{7}{8}$	620		X				X		X		15.5		18.6
						X				X		X		18.6		
Vertical Configuration (Navy) ³																
22,000 (HB022)	22,000	21,000 ⁴	72 $\frac{1}{4}$ x 31 $\frac{1}{4}$ x 12 $\frac{1}{2}$	270		208/ 230		X		60				10.6		N/A
34,000 (HB036)	33,400	35,000 ⁴	72 $\frac{1}{4}$ x 39 $\frac{1}{4}$ x 15	432		208/ 240			X	60				16.0		N/A
Sleeve Mounted Configuration (Navy) ³																
22,000 (HE022R 6S)	22,000	21,000 ⁴	24 $\frac{1}{4}$ x 31 $\frac{1}{4}$ x 22 $\frac{1}{2}$	275		208/ 230		X		60				10.6		N/A
34,000 (HE036R 6S)	33,400	35,000 ⁴	44 x 39 $\frac{1}{4}$ x 28 $\frac{1}{2}$	423		208/ 240			X	60				16.0		N/A

¹Sources of data are Reference 27 in Appendix I-2 for Army ECU's and Reference 35 for Navy units.

²Cooling ratings for the Army horizontal ECU's were determined at 125°F dry bulb (db) outside temperature and 90°F db inside temperature. For the Army vertical units, except the 18,000 Btuh unit, the outside temperature was 120°F db and the inside temperature was 90°F db; for the 18,000 Btuh unit, it was 125°F db and 90°F db. The Navy units were rated at 95°F db outside and 80°F db inside.

³See "Heat Pump" in Appendix I-1.

⁴For installed supplementary heaters, see Reference 35.

Figure I-2. STANDARD MILITARY ENVIRONMENTAL CONTROL UNITS ¹

Climatic Category ²	Ambient Air Temperatures, °F (°C) ³			Relative Humidity
	High	Low	Highest/Lowest Ever Recorded ⁴	
A1 Hot dry	120 (49)	90 (32)	136 (58)	3% - 8%
A2 Intermediate hot dry	111 (44)	86 (30)	127 (53)	8% - 40%
B1 Wet warm	Nearly constant at 75 (24) throughout the 24 hours		-	95% - 100%
B2 Wet hot	95 (35)	79 (26)	-	74% @ 95° (1500 hrs) 100% @ 79° (2400 - 0600 hrs)
B3 Humid hot coastal desert	106 (41)	88 (31)	-	60% @ 106° (1500 hrs) 88% @ 88° (2400 - 0600 hrs)
C0 Mild cold	21 (-6)	-2 (-19)	-11 (-24)	Tending to saturation
C1 Intermediate cold	-6 (-21)	-24 (-31)	-44 (-42)	Tending to saturation
C2 Cold	-35 (-37)	-51 (-46)	-69 (-56)	Tending to saturation
C3 Severe cold	Nearly constant at -60 (-51) throughout the 24 hours		-	Tending to saturation
C4 Extreme cold	Nearly constant at -71 (-57) throughout the 24 hours		-96 (-71)	Tending to saturation

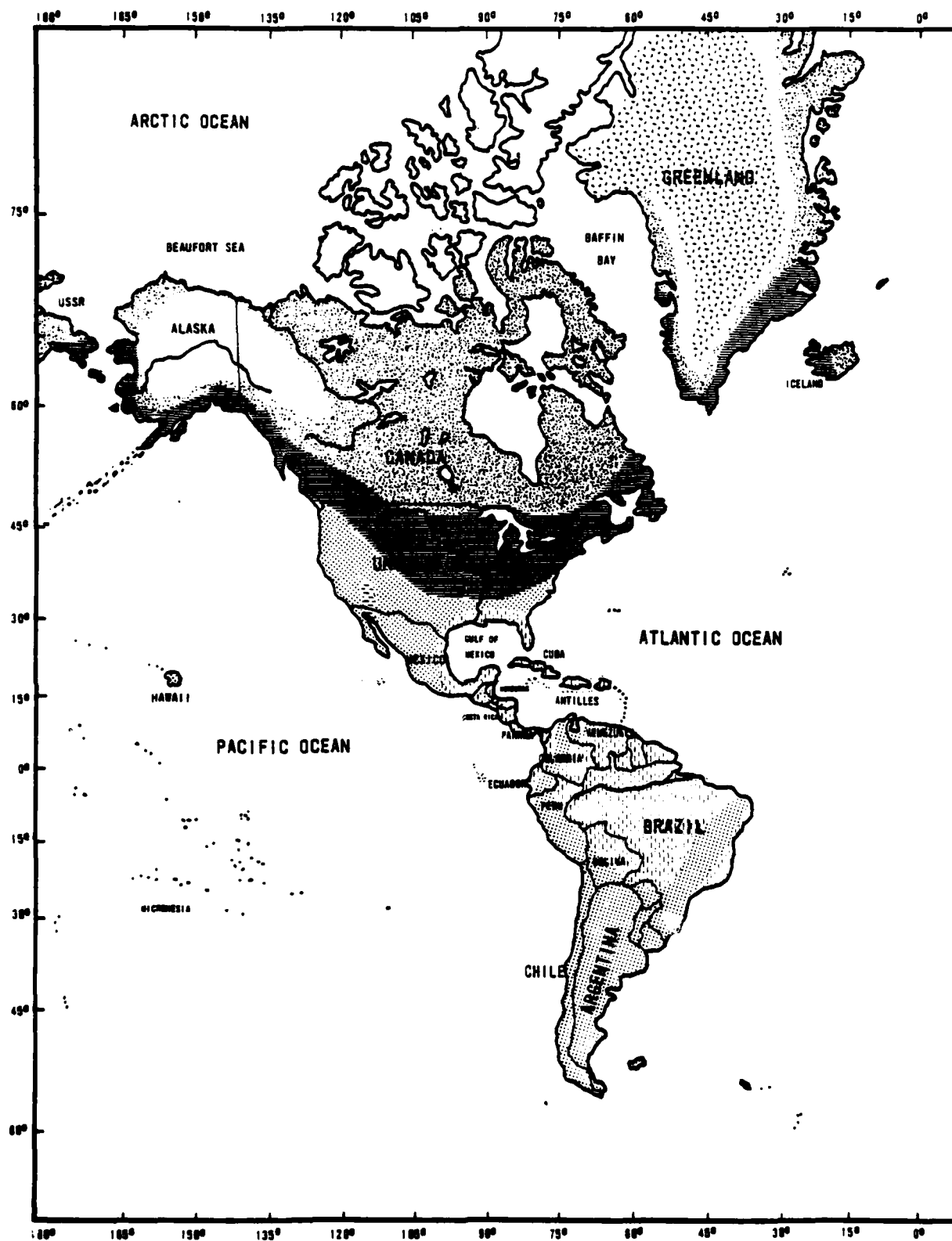
¹From Reference 15.

²See Figure I-4.

³For categories A1, A2, and C0 through C4, temperature is the principal consideration. For categories B1, B2, and B3, humidity is the principal consideration. All temperatures are dry bulb readings.

⁴Highest temperature where heat is principal consideration and lowest where cold is principal consideration.

Figure I-3. HIGH AND LOW TEMPERATURES AND RELATIVE HUMIDITIES FROM CHARACTERISTIC DIURNAL CYCLE DURING HOTTEST OR COLDEST MONTH OF THE YEAR¹



IG A

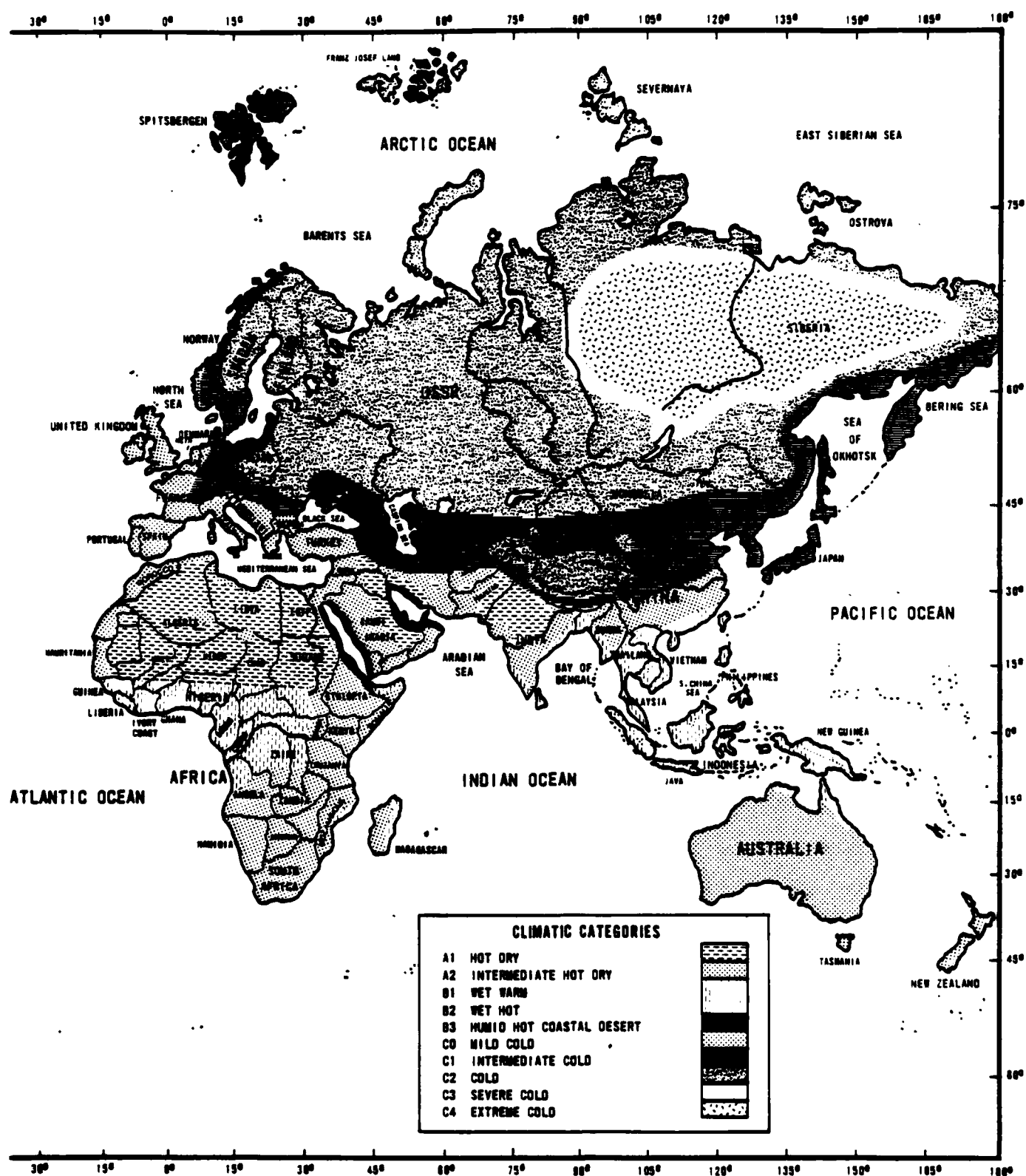


Figure I-4. LOCATION OF CLIMATIC CATEGORIES
(Includes facing page)

SECTION II - SELECTION OF ENVIRONMENTAL CONTROL UNITS (ECU)

II-1. Introduction

This section gives you simple and easily followed steps for selecting environmental control units (ECU) for standard, small, military shelters. These steps do not get into ECU design; rather, they guide you in the selection of suitable standard units from those already available for military use. To make a selection, you will need to know:

- How to estimate the summer cooling requirement.
- How to estimate the winter heating requirement.
- How to select an adequate ECU.
- How to select an auxiliary heater, if one is needed.

This easy method provided here will give you acceptable results for most military systems. If your system needs special conditions such as pre-humidity control, then you may need special engineering help. To see the method described in this section was developed, look in Appendix II-1.

A	B	C	D	E	F	CLIMATIC CATEGORIES	G	H
STANDARD SHELTER DESIGNATION	SHELTER SIZE (HxWxL) (FT.)	SUMMER SOLAR & CONDUCTION HEAT GAIN (BTUH)	WINTER CONDUCTION HEAT LOSS (BTUH)	SUMMER COOLING FACTOR	WINTER HEATING FACTOR		SUMMER VENTILATION HEAT GAIN (BTUH/CFM)	WINTER VENTILATION HEAT LOSS (BTUH/CFM)
Non-Expandable:								
Army S-250	6x6x7	3,750	6,200	1.49	1.00	A1 HOT DRY	46	76
Army S-280	7x7x12	7,060	11,580	1.31	1.00	A2 MOD HOT DRY	34	76
Navy MF ISO ¹ (Single)	8x8x20	8,272	13,440	NA	1.00	B1 WET WARM	NA	76
Navy MF ISO (Double)	8x16x20	12,984	21,280	1.00	1.00	B2 WET HOT	100	76
ISO Army GP	8x8x20	11,630	18,820	1.26	1.00	B3 HUMID HOT	124	76
Expandable:								
Air Force S-520	7x22x12	15,830	25,430	1.31	1.00	C0 MILD COLD	39	76
ISO Army 1 side expandable	8x15x20	17,580	28,420	1.00	1.36	C1 MOD COLD	39	104
ISO Army 2 sides expandable	8x22x20	23,640	38,020	1.00	1.71	C2 COLD	39	131
				1.00	1.86	C3 SEVERE COLD	39	141
				1.00	2.00	C4 EXTREME COLD	39	152

Baseline temperatures inside shelter: Summer, 78°F; Winter, 70°F.

Figure II-1. ESTIMATING DATA FOR COOLING AND HEATING REQUIREMENTS

¹When single MF shelters are attached to the integration unit (see footnote to Figure I-1), each shelter, including the integration unit, is treated as a separate unit for determination of cooling and heating requirements.

II-2. How to Estimate the Summer Cooling Requirement

Reproduce the worksheet shown on page II-13. Fill in the data at the top of the sheet and then follow steps 1 through 5 of the instructions. If you are planning for a B1 region (see Figure I-4), anticipate a worldwide, as opposed to a regional, application or plan that CB collective protection equipment will be required, you should read paragraphs II-3, II-4, and II-5 before starting on the worksheet.

II-3. Precise Humidity Control (PHC)

Military ECU's are generally not very satisfactory as dehumidifiers under conditions of high humidity. When confronted with a situation of very high humidity and not much cooling to be done, such as Climatic Category B1 with a nearly constant temperature of 75°F, they cannot handle the problem. This is reflected in Figure II-1.

- Military ECU's are designed not for PHC but primarily for sensible (dry) cooling. They cannot dehumidify unless they are also cooling. What dehumidification is accomplished is only incidental to the cooling process and, in high humidity, the ECU evaporator coils, especially on some vertical configurations, experience water carryover problems and tend to throw water out of the return air louvers.

- PHC needs humidistat control of cooling, a reheat capability roughly equal to cooling, and a reheat temperature control. Military ECU's do not have these. They would have to be provided by the user as add-ons, as required, and adding them to military ECU's is a difficult job. It requires extensive knowledge of psychrometrics, a familiarity with the internal circuitry of the equipment, precise load evaluation, and design experience with the necessary add-on features. All this is well beyond the scope of this handbook to cover. The job should be undertaken only by someone with the necessary expertise and a full and proven capability, ideally, the ECU's original manufacturer. If you need PHC, it is recommended that you contact one or more of the leading manufacturers of air conditioners to discuss in specific terms any problems and requirements you may have with regard to PHC.

A major consideration in using PHC is the power requirement. Because of the need for full constant cooling plus about equal reheat, PHC imposes a high power demand which must be met. This could result in as much as twice the normal cooling power consumption.

II-4. Worldwide Application

The cooling requirement determination of Worksheet Part I and as illustrated in the sample problem of paragraph II-8 is for a specific climatic category applying to a certain region of the world. You may have need for systems capable of worldwide use. In such cases, complete two worksheets using the climatic categories which provide the most extreme conditions: A1 and B3. Using the Column E and G values of 1.49 and 46 for A1 and 1.26 and 124 for B3, compute the total cooling requirement. Use the one which gives the larger requirement.

II-5. If CB Collective Protection Equipment is to be Used

Collective protection equipment will add to the cooling load of the ECU. The CB filter-blower unit blows air into the shelter at 10°F to 15°F above outside temperature. You must take this into consideration since it may require an increase in the size of the ECU you would normally select. Paragraph V-10, Section V, explains how to do this.

II-6. How to Estimate the Winter Heating Requirement

Reproduce Worksheet Part II shown on page II-14. Fill in the data at the top of the sheet and then follow Steps 6 through 12 of the instructions.

II-7. How to Select an Adequate ECU

You are now ready to make a preliminary selection of an ECU. Final selection will depend on several additional considerations explained in paragraphs II-9 through II-12. For now, the requirement is to narrow the field of possible ECU's by selecting a unit which is adequate but not unnecessarily oversized. MIL-A-52767B and MIL-STD-1408, from which you will select the ECU, lists (as does Figure I-2 of this Handbook) a number of categories of units available. Normally, you should limit your selection to horizontal compact and vertical compact units; the Worksheet Part II addresses these two types. You need to explore the others only if there is a special requirement for which a conventional or developmental type is particularly suited; the procedure will be the same regardless of the type. Reproduce Worksheet Part III, shown on pages II-15 and II-16, fill in the top portion and then follow Steps 13 and 14 of the instructions and, if appropriate, Steps 15, 16, and 17.

II-8. Sample Problem

This provides you with an illustration of how the procedures offered in Paragraphs II-2, II-6, and II-7 will work.

- Assume:

- Shelter: Navy MF ISO (single)
- Location: Ramstein, Germany
- Occupants: 3 people
- Design inside temperature: 75°F (desired inside temperature)
- Electrical equipment/lights: Maximum at any one time - 6,000 watts; minimum - 0 watts
- Available power: AC 208 volts, 3 phase, 50/60 Hz, 4 wires

● From the completed Worksheet Part I (Figure II-2), the cooling requirement is 33,091 Btuh. Note that the solar/conduction heat gain was adjusted for the fact that your desired interior temperature is different from the 78°F on which the values in Column C of Figure II-1 are based. Figure II-5 was used to determine the correction factor, in this case 1.07.

WORKSHEET PART I - COOLING REQUIREMENT ESTIMATE

Shelter Designation NAVY MFO 150 (SINGLE)
 Shelter Location RAMSTEIN, GERMANY
 Shelter Occupants (Avg. No. of Persons) 3
 Required (Design) Inside Temperature 75°F

(If only heating is required, skip steps 1 through 5 and go to Worksheet II)

STEP

1. Solar/conduction heat gain: $\frac{8272}{(1a)} \text{ Btuh} \times \frac{1.00}{(1b)} \times \frac{1.07}{(1c)} = \frac{8,851}{(1)} \text{ Btuh}$
2. Heat gain from electrical equipment/lights: $\frac{6000}{(2a)} \text{ watts} \times \frac{3.4}{(2)} \text{ Btuh/watt} = \frac{20,400}{(2)} \text{ Btuh}$
3. Heat gain from personnel: $\frac{3}{(3a)} \text{ persons} \times \frac{500}{(3)} \text{ Btuh/person} = \frac{1,500}{(3)} \text{ Btuh}$
4. Heat gain from ventilation: $\frac{39}{(4a)} \text{ Btuh/cfm} \times \frac{3}{(4b)} \text{ persons} \times \frac{20}{(4)} \text{ cfm/person} = \frac{2,340}{(4)} \text{ Btuh}$
5. Total cooling requirement: $(1) + (2) + (3) + (4) = \frac{33,091}{(5)} \text{ Btuh}$

Where to find (1a): Figure II-1, Column C

(1b): Figure II-1, Column E

(1c): Figure II-5

(2a): Equipment and lights in shelter

(3a): Top of worksheet

(4a): Figure II-1, Column G

(4b): Top of worksheet

INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 1 - SOLAR/CONDUCTION HEAT GAIN

- Find the shelter you want to cool in Column A of Figure II-1.
- For this type of shelter pick out the summer cooling load from Column C and put it in worksheet space (1a).
- Find the location of the shelter on the map, Figure I-4, and note the pattern.
- Match the pattern with Column E. Pick out the proper cooling factor and put it in worksheet space (1b).
- With your design inside temperature, turn to Figure II-5 and, using the Solar Conduction Heat Gain Curve, find the correction factor and put it in space (1c).
- Perform multiplication and put the result in space (1).

STEP 2 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of all electrical equipment and lights to be used in the shelter.
- Put the sum in space (2a) and multiply it by 3.4.
- Put the result in space (2).

STEP 3 - HEAT GAIN FROM PERSONNEL

- Put the number of people to occupy the shelter in space (3a).
- Multiply by 500 and put the result in space (3).

STEP 4 - HEAT GAIN FROM VENTILATION

- With the same climatic category pattern used in Step 1, find the summer heat gain factor from Column G and put it in worksheet space (4a).
- Put the number of people in the shelter in space (4b).
- Perform the multiplication indicated on the worksheet and write the result in space (4).

STEP 5 - TOTAL COOLING REQUIREMENT

- Perform the addition and put the sum in space (5). This is the cooling requirement for selecting the ECU.

Figure II-2. SAMPLE PROBLEM-WORKSHEET PART I

- From the completed Worksheet Part II (Figure II-3), the heating requirement is 24,548 Btuh.

- From the completed Worksheet Part III (Figure II-4):

- Steps 13 and 14 show that adequate cooling requires a standard ECU with a nominal capacity of 36,000 Btuh. The actual rating of the horizontal unit is 38,335 Btuh and the vertical unit is 35,343. Both units are well above the requirement so you may select the configuration best suited to your needs. You should have noticed that the final ECU ratings were adjusted (de-rated). This de-rating is done because in Figure I-2 the ECU is rated for an interior temperature of 80°F at outdoor temperatures up to 105°F. At lower indoor temperatures, in this case 75°F, it is necessary to de-rate the air conditioner. Had you been selecting a system for a climatic area with outdoor design temperatures above 105°F, the de-rating factor would have been 0.805. You use Figure II-5 to obtain these factors.

Before proceeding, read paragraphs II-9 and II-10.

- Step 17 determined that a pair of horizontal units with a combined capacity of 34,596 Btuh or a pair of vertical ECU's at 36,092 Btuh will be adequate and reasonably sized. It also shows that the combined heating capacities are close enough to the requirement to be acceptable in view of the fact that heat generated by personnel and electrical equipment were not considered in the Worksheet Part II computations.

- You have now made your preliminary selection. Final selection will depend upon any adjustments you make after considering paragraphs II-9 through II-12 and the mounting method required.

II-9. Proper Sizing

The ECU you finally select should be adequate but not oversized for the cooling load you calculated on Worksheet Part I. Sizing the cooling unit as closely as possible to the requirement is important because of the dehumidification process. An oversize ECU will cool the shelter quickly, switch to a non-cooling mode and remain in a non-cooling mode until it is needed to cool again. While in the non-cooling mode, it is not dehumidifying the shelter. A smaller ECU will cool more slowly and, because its capacity is close to the requirement, will cool almost constantly; it therefore will be also constantly dehumidifying the shelter. By contrast, oversize of the heating capacity does not create a similar problem. Actually, heating oversize may be beneficial in overcoming heat loss because of doors opening and also for bringing an unused shelter up to the desired temperature more quickly before sensitive equipment is turned on.

II-10. Multiple Units

The use of two or more ECU's to satisfy a single requirement offers several potential advantages:

- It may be possible to size closer to the requirement.

WORKSHEET PART II - HEATING REQUIREMENT ESTIMATE

Shelter Designation NAVY MFO 150 (SINGLE)
 Shelter Location RAMSTEIN, GERMANY
 Shelter Occupants (Avg. No. of Persons) 3

STEP

6. Conduction heat loss: $\frac{13,440}{(6a)} \text{ Btuh} \times \frac{1.36}{(6b)} = \frac{18,278}{(6)} \text{ Btuh}$
7. Vent heat loss: $\frac{104.5}{(7a)} \text{ Btuh/cfm} \times \frac{3}{(7b)} \text{ pers} \times 20 \text{ cfm/pers} = \frac{6,270}{(7)} \text{ Btuh}$
8. Heating requirement: $(6) + (7) = (\text{SEE STEP 8 OF INSTRUCTIONS, BELOW.}) \quad \frac{24,548}{(8)} \text{ Btuh}$
9. Heat gain from elec equip/lights: $\frac{\quad}{(9a)} \text{ watts} \times 3.4 \text{ Btuh/watt} = \frac{\quad}{(9)} \text{ Btuh}$
10. Heat gain from personnel: $\frac{\quad}{(10a)} \text{ pers} \times 500 \text{ Btuh/pers} = \frac{\quad}{(10)} \text{ Btuh}$
11. Total heat gain: $(9) + (10) = \frac{\quad}{(11)} \text{ Btuh}$
12. Net heating requirement: $(8) - (11) = \frac{\quad}{(12)} \text{ Btuh}$

Where to find (6a): Figure II-1, Column D (7b): Top of worksheet
 (6b): Figure II-2, Column F (9a): Equipment and lights in shelter
 (7a): Figure II-2, Column H (10a): Top of worksheet

INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 6 - CONDUCTION HEAT LOSS

- Find the shelter you want to cool in Column A of Figure II-1.
- For this type of shelter, pick out the winter heating load from Column D and put it in worksheet space (6a).
- Find the location of the shelter on the map, Figure I-4, and note the pattern.
- Match the pattern with Column F, Figure II-1. Pick out the proper cooling factor and put it in worksheet space (6b).
- Perform the multiplication and put the result in space (6).

STEP 7 - VENTILATION HEAT LOSS

- With the climatic category pattern used in Step 6, find the winter heat loss factor in Column H, Figure II-1, and put it in space (7a).
- Put the number of people in the shelter in space (7b).
- Perform the multiplication and put the result in space (7).

STEP 8 - HEATING REQUIREMENT

- Add (6) and (7) and put the sum in worksheet space (8). This is your heating requirement if your operational equipment must be warmed before it can be safely started. In this case, use this figure in Worksheet Part III. If you do not require preheating for the equipment, your energy requirements can be reduced by recognizing the heat gained from electrical equipment and personnel in the shelter and following Steps 9 through 12.

STEP 9 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of minimum electrical equipment and lights to be used during shelter operation.
- Put the sum in space (9a) and multiply it by 3.4.
- Put the results in space (9).

STEP 10 - HEAT GAIN FROM PERSONNEL

- Put the number of people in space (10a) and multiply by 500.
- Put the result in space (10).

STEP 11 - TOTAL HEAT GAIN

- Add (9) and (10) and put the sum in space (11).

STEP 12 - NET HEATING REQUIREMENT

- Subtract (11) from (8) and put the difference in space (12). This is the heating requirement for selecting the ECU.

Figure II-3. SAMPLE PROBLEM-WORKSHEET PART II

WORKSHEET PART III - SELECTION OF ECU (Page 1 of 2)

Shelter Designation: NAVY MFO ISO(SINGLE); Location: RAMSTEN, GERMANY
 Cooling Requirement: 33,091 Btuh; Heating Requirement: 24,548 Btuh
 Design Inside Temperature: 75 °F; Climatic Category: C1
 Power Source Available: AC 208 volts, 3 phase, 50/60 Hertz, 4 wires
 Reference Figure I-2 and MIL-A-52767B for ECU data.

STEP

HORIZONTAL COMPACT

VERTICAL COMPACT

SINGLE ECU

13. Nominal capacity (Btuh):	<u>36,000</u> (13a)	<u>36,000</u> (13b)
14. Actual rating (Btuh):		
Cooling:	<u>41,000</u> x <u>0.935</u> = <u>38,335</u> (14a) (14b) (14c)	<u>37,800</u> x <u>0.935</u> = <u>35,343</u> (14d) (14e) (14f)
Heating:	<u>31,200</u> (14g)	<u>28,600</u> (14h)

INSTRUCTIONS FOR COMPLETING WORKSHEET

SINGLE ECU

STEP 13 - NOMINAL ECU CAPACITY

- From Figure I-2, select a horizontal and a vertical ECU each with a nominal capacity equal to the next size larger than the cooling requirement. Put these sizes in spaces (13a) and (13b).

STEP 14 - ACTUAL RATING AND SELECTION

- From Figure I-2, find the cooling and heating "Rating Btuh" for these two ECU's. Put these into spaces (14a) and (14g) for the horizontal ECU and (14d) and (14h) for the vertical ECU.
- With your climatic category and desired interior temperature (design inside temperature), turn to Figure II-5. Using Curve A or Curve B, as determined by your climatic category, find the correction factor and put it into spaces (14b) and (14e). Multiply to determine the ECU actual rating.
- If cooling rating of either or both of these is equal to or slightly larger than the cooling requirement, you have completed the preliminary selection process and Steps 15 and 16 may be skipped.
- If the heating rating is equal to or larger than the requirement, no supplementary heater will be required and paragraph II-13 may be skipped. If the heating rating is smaller than the requirement, go to paragraph II-13.
- You should complete Steps 15 and 16 if the units in Step 14 are smaller or much larger than the requirement.

Figure II-4a. SAMPLE PROBLEM-WORKSHEET PART III (1 OF 2)

WORKSHEET PART III - SELECTION OF ECU (Page 2 of 2)

DUAL ECU'S

HORIZONTAL COMPACT

VERTICAL COMPACT

15. Nominal capacities (8tuh):

$$\frac{18,000}{(15a)} \times 2 = \frac{36,000}{(15b)}$$

$$\frac{18,000}{(15c)} \times 2 = \frac{36,000}{(15d)}$$

16. Actual ratings (8tuh):

Cooling: $\frac{18,500}{(16a)} \times \frac{0.935}{(16b)} = \frac{17,298}{(16c)}$

Cooling: $\frac{19,300}{(16d)} \times \frac{0.935}{(16e)} = \frac{18,046}{(16f)}$

Heating: $\frac{14,300}{(16g)}$

Heating: $\frac{12,000}{(16h)}$

17. Closest combination:

Cooling: 2 X (16a) or (16f) = $\frac{34,596}{(17a)}$ OR

$\frac{36,092}{(17b)}$

Heating: 2 X (16g) or (16h) = $\frac{28,600}{(17c)}$ OR

$\frac{24,000}{(17d)}$

INSTRUCTIONS FOR COMPLETING WORKSHEET

DUAL ECU'S

STEP 15 - NOMINAL CAPACITIES

- From Figure I-2, select the smallest pair of nominal capacities that satisfies the cooling requirement. Put these ratings in spaces (15a) and (15c). Multiply them by 2 and put the results in spaces (15b) and (15d). If the pair looks close, proceed with Step 16; if not, select another pair.

STEP 16 - ACTUAL RATINGS

- From Figure I-2, find the cooling and heating ratings for the vertical and horizontal ECU's picked in Step 15; enter these in spaces (16a), (16d), (16g) and (16h). Enter in spaces (16b) and (16e) the correction factor used in (14b) and (14e). Multiply and put the results in spaces (16c) and (16f).

STEP 17 - CLOSEST COMBINATION OF ECU'S

- If a pair of ECU's satisfies and is closer to the cooling requirement than the single units of Step 14, the pair, shelter space permitting, should be your preliminary selection. Heating consideration is the same as for Step 14.

Figure II-4b. SAMPLE PROBLEM-WORKSHEET PART III (2 OF 2)

- The flexibility of mounting at two or more points on the shelter might permit a solution to the distribution problem without the need for ducting.

- The calculated cooling requirement is based on the anticipated worst case. During times that the worst case does not exist, the cooling requirement would be reduced.

- Use of a single oversized unit could result in the problem discussed in paragraph II-9. Multiple units provide a flexibility which might avoid this problem.

- Much of the time when the load is less than the maximum computed, one of the pair of ECU's may meet the cooling requirement. Less power would then be consumed. Further, with two or more units, there would exist the desirable situation in which there would be a back-up ECU during the periods of lower requirements.

As a rule, when two or more ECU's are used, it is a good idea to make them all the same. This will not only ease the logistical support burden but will also improve the back-up flexibility. In a technical sense, however, there is no significant drawback to mixing types and capacities (as long as power requirements are compatible) and there may be an occasional good reason for doing so. For example, there could be a case in which normally operating mission equipment generates a moderate amount of heat but where installed special mission equipment, which operates only infrequently, is a big heat producer. In this case, a small ECU may cool adequately for normal operations but a larger ECU may be a necessity when the special equipment is in use.

II-11. Reducing Oversize

The ECU size and power usage increase significantly as rated cooling capacity increases. Since shelters are usually cramped for space and power is often at a premium, consideration should be given to using the lowest capacity ECU that reasonable comfort and equipment requirements will permit. For example, if:

- An inside temperature of 85°F, instead of 78°F, is tolerable, considering the benefits to comfort that the dehumidification effected by the ECU will provide, and

- A reduced ventilation requirement is acceptable, considering that since the onset of the energy shortage a more conservative value of 5 cfm per person has been established by Reference 4, Appendix I-2, then --

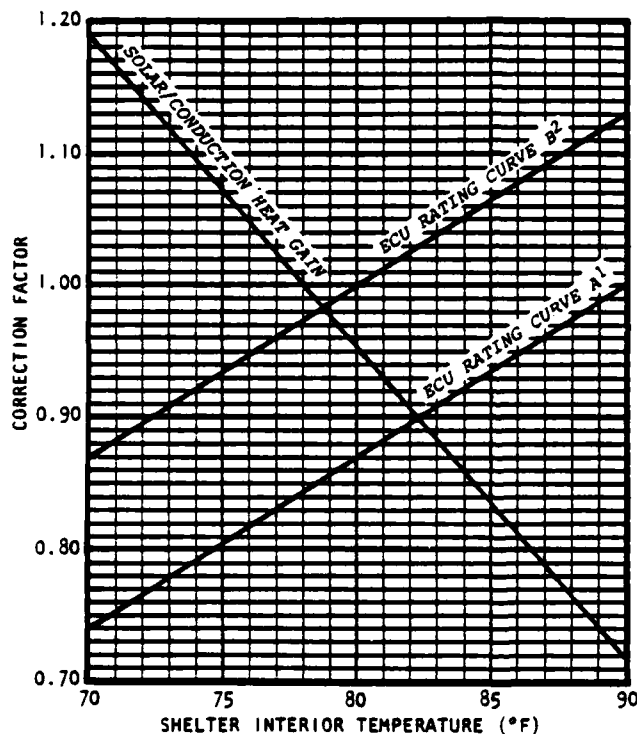
The selection process of Section II (and the criteria of Appendix II-1) would include the following adjustments:

- Reduce the solar/conduction cooling load (Figure II-1, Column C). Select from Figure II-5 the solar/conduction correction factor for 85°F (0.835). Recompute Worksheet Step 1 by multiplying the value in Worksheet space (1) by the correction factor, 0.835.

- Reduce the ventilation requirement from 20 cfm per person to 5 cfm per person and recompute worksheet Step 4.

- Retotal spaces (1) through (4) to obtain an adjusted cooling requirement.

- Increase the rated cooling capacity of the next smaller ECU. Using Curve B of Figure II-5 (if outside temperature were over 105°F, you would use Curve A), select the ECU rating correction factor (1.064 or 1.06). Multiply the rated cooling capacity of the ECU by the factor 1.06 to obtain the adjusted cooling rating. Compare the adjusted rating with the adjusted requirement. If the smaller ECU now meets the cooling requirement, it may be selected. This procedure may be used in the same manner for other interior shelter temperatures within the range of Figure II-5.



¹CURVE A FOR DESIGN OUTSIDE TEMPERATURES OVER 105°F. (CLIMATE CATEGORIES A1, A2, AND B3; SEE FIGURE I-3.)

²CURVE B FOR DESIGN OUTSIDE TEMPERATURES UP TO 105°F. (ALL CLIMATE CATEGORIES OTHER THAN A1, A2 AND B3; SEE FIGURE I-3.)

Figure II-5. CORRECTION FACTORS FOR ADJUSTING FROM SHELTER INTERIOR DESIGN TEMPERATURE

II-12. The Value of Shading the Shelter

As you may have noted in completing Worksheet Part I, a significant source of heat which the ECU must handle is solar radiation subsequently conducted through the shelter walls and roof. You can reduce the heat gain from this source by approximately 45% if you shade the shelter. To reach this reduction, the shade should be complete, that is, no sun filtering through.

¹The method used for estimating the 45% is explained in Appendix II-2.

Adequate shade can be provided by dense tree foliage if such is available. If not, you may erect a canvas rectangle, perhaps combined with your camouflage scheme. The canvas should be as shown in Figure II-6. The overhang should be the same on all four sides of the shelter. The distance of the canvas above the shelter should always be at least one foot. There is no noticeable advantage to making it higher than this; but, if some consideration requires that it be, the overhang distance should then become the height of the shelter plus the distance between the canvas and the shelter roof.

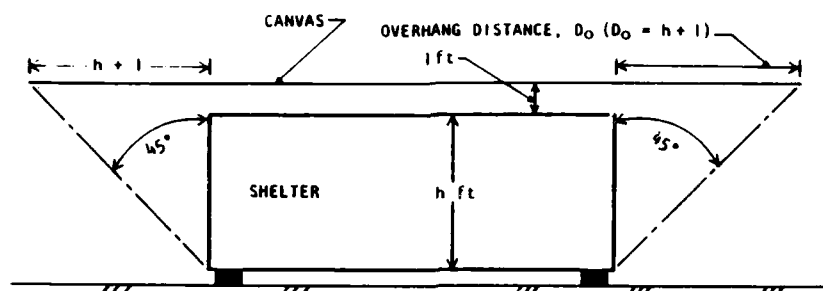


Figure II-6. SHADING THE SHELTER

II-13. How to Select a Supplementary Heater

Cooling is the primary concern in selecting an ECU. In most of the cases you will encounter, it is probable that the ECU which was sized for cooling will be adequate also for heating. However, if the net heating requirement which you determined in Step 12 exceeds the rated heating capacity of the selected ECU (or ECU's), then you will require a supplemental heater. You will find heaters applicable to shelters listed in MIL-STD-1407 under the heading: "Heater, Space, Blower Type". The heater you select will depend on the specifics of your situation. For example:

- If you need to keep the temperature in the entire shelter at a fairly uniform level, a fuel burning space heater with a blower may be required. The heating requirement would be that determined on Worksheet Part II.

- If you want to heat just the space around an individual occupant, you may need only a small portable electric space heater or a small fuel burning heater.

- If floor space is at a premium, outside mounting of a duct type heater may be needed.

- Electric heaters increase power consumption but all fuel burning heaters require an exhaust to the outside.

• In short, identifying potential heaters from MIL-STD-1407 is a relatively simple matter but selecting one depends upon the definition of your requirement.

II-14. A Caution on Ventilation

Instructions should be included in the operating procedures for the shelter not to exceed the ventilation specified in Steps 4 and 7. When the fresh air damper is manually adjusted open to provide additional fresh air for ventilation to exceed 20 cfm, there results a substantial penalty in air conditioner cooling load in hot and humid conditions and in heater load in colder climatic conditions.

WORKSHEET PART I - COOLING REQUIREMENT ESTIMATE

Shelter Designation _____

Shelter Location _____

Shelter Occupants (Avg. No. of Persons) _____

Required (Design) Inside Temperature _____ °F

(If only heating is required, skip steps 1 through 5 and go to Worksheet II)

STEP

1. Solar/conduction heat gain: _____ Btuh x _____ x _____ = _____ Btuh
(1a) (1b) (1c) (1)
2. Heat gain from electrical equipment/lights: _____ watts x 3.4 Btuh/watt = _____ Btuh
(2a) (2)
3. Heat gain from personnel: _____ persons x 500 Btuh/person = _____ Btuh
(3a) (3)
4. Heat gain from ventilation: _____ Btuh/cfm x _____ persons x 20 cfm/person = _____ Btuh
(4a) (4b) (4)
5. Total cooling requirement: (1) + (2) + (3) + (4) = _____ Btuh
(5)

Where to find (1a): Figure II-1, Column C

(3a): Top of worksheet

(1b): Figure II-1, Column E

(4a): Figure II-1, Column G

(1c): Figure II-5

(4b): Top of worksheet

(2a): Equipment and lights in shelter

INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 1 - SOLAR/CONDUCTION HEAT GAIN

- Find the shelter you want to cool in Column A of Figure II-1.
- For this type of shelter pick out the summer cooling load from Column C and put it in worksheet space (1a).
- Find the location of the shelter on the map, Figure I-4, and note the pattern.
- Match the pattern with Column E. Pick out the proper cooling factor and put it in worksheet space (1b).
- With your design inside temperature, turn to Figure II-5 and, using the Solar Conduction Heat Gain Curve, find the correction factor and put it in space (1c).
- Perform multiplication and put the result in space (1).

STEP 2 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of all electrical equipment and lights to be used in the shelter.
- Put the sum in space (2a) and multiply it by 3.4.
- Put the result in space (2).

STEP 3 - HEAT GAIN FROM PERSONNEL

- Put the number of people to occupy the shelter in space (3a).
- Multiply by 500 and put the result in space (3).

STEP 4 - HEAT GAIN FROM VENTILATION

- With the same climatic category pattern used in Step 1, find the summer heat gain factor from Column G. and put it in worksheet space (4a).
- Put the number of people in the shelter in space (4b).
- Perform the multiplication indicated on the worksheet and write the result in space (4).

STEP 5 - TOTAL COOLING REQUIREMENT

- Perform the addition and put the sum in space (5). This is the cooling requirement for selecting the ECU.

WORKSHEET PART II - HEATING REQUIREMENT ESTIMATE

Shelter Designation _____

Shelter Location _____

Shelter Occupants (Avg. No. of Persons) _____

STEP

6. Conduction heat loss: _____ Btuh x _____ = _____ Btuh
(6a) (6b) (6)
7. Vent heat loss: _____ Btuh/cfm x _____ pers x 20 cfm/pers = _____ Btuh
(7a) (7b) (7)
8. Heating requirement: (6) + (7) = _____ Btuh
(8)
9. Heat gain from elec equip/lights: _____ watts x 3.4 Btuh/watt = _____ Btuh
(9a) (9)
10. Heat gain from personnel: _____ pers x 500 Btuh/pers = _____ Btuh
(10a) (10)
11. Total heat gain: (9) + (10) = _____ Btuh
(11)
12. Net heating requirement: (8) - (11) = _____ Btuh
(12)

Where to find (6a): Figure II-1, Column D (7b): Top of worksheet
(6b): Figure II-2, Column F (9a): Equipment and lights in shelter
(7a): Figure II-2, Column H (10a): Top of worksheet

INSTRUCTIONS FOR COMPLETING WORKSHEET

STEP 6 - CONDUCTION HEAT LOSS

- Find the shelter you want to cool in Column A of Figure II-1.
- For this type of shelter, pick out the winter heating load from Column D and put it in worksheet space (6a).
- Find the location of the shelter on the map, Figure I-4, and note the pattern.
- Match the pattern with Column F, Figure II-1. Pick out the proper cooling factor and put it in worksheet space (6b).
- Perform the multiplication and put the result in space (6).

STEP 7 - VENTILATION HEAT LOSS

- With the climatic category pattern used in Step 6, find the winter heat loss factor in Column H, Figure II-1, and put it in space (7a).
- Put the number of people in the shelter in space (7b).
- Perform the multiplication and put the result in space (7).

STEP 8 - HEATING REQUIREMENT

- Add (6) and (7) and put the sum in worksheet space (8). This is your heating requirement if your operational equipment must be warmed before it can be safely started. In this case, use this figure in Worksheet Part III. If you do not require preheating for the equipment, your energy requirements can be reduced by recognizing the heat gained from electrical equipment and personnel in the shelter and following Steps 9 through 12.

STEP 9 - HEAT GAIN FROM ELECTRICAL EQUIPMENT/LIGHTS

- Add the power rating (watts) of minimum electrical equipment and lights to be used during shelter operation.
- Put the sum in space (9a) and multiply it by 3.4.
- Put the results in space (9).

STEP 10 - HEAT GAIN FROM PERSONNEL

- Put the number of people in space (10a) and multiply by 500.
- Put the result in space (10).

STEP 11 - TOTAL HEAT GAIN

- Add (9) and (10) and put the sum in space (11).

STEP 12 - NET HEATING REQUIREMENT

- Subtract (11) from (8) and put the difference in space (12). This is the heating requirement for selecting the ECU.

WORKSHEET PART III - SELECTION OF ECU (Page 1 of 2)

Shelter Designation: _____; Location: _____
 Cooling Requirement: _____ Btuh; Heating Requirement: _____ Btuh
 Design Inside Temperature: _____ °F; Climatic Category: _____
 Power Source Available: _____ volts, _____ phase, _____ Hertz, _____ wires
 Reference Figure I-2 and MIL-A-52767B for ECU data.

STEP

HORIZONTAL COMPACT

VERTICAL COMPACT

SINGLE ECU

13. Nominal capacity (Btuh):	_____	(13a)		_____	(13b)
14. Actual rating (Btuh):					
Cooling:	_____	X	_____	=	_____
	(14a)		(14b)		(14c)
				X	_____
				(14d)	(14e)
				=	_____
					(14f)
Heating:	_____				_____
					(14g)
					(14h)

INSTRUCTIONS FOR COMPLETING WORKSHEET

SINGLE ECU

STEP 13 - NOMINAL ECU CAPACITY

- From Figure I-2, select a horizontal and a vertical ECU each with a nominal capacity equal to the next size larger than the cooling requirement. Put these sizes in spaces (13a) and (13b).

STEP 14 - ACTUAL RATING AND SELECTION

- From Figure I-2, find the cooling and heating "Rating Btuh" for these two ECU's. Put these into spaces (14a) and (14g) for the horizontal ECU and (14d) and (14h) for the vertical ECU.
- With your climatic category and desired interior temperature (design inside temperature), turn to Figure II-5. Using Curve A or Curve B, as determined by your climatic category, find the correction factor and put it into spaces (14b) and (14e). Multiply to determine the ECU actual rating.
- If cooling rating of either or both of these is equal to or slightly larger than the cooling requirement, you have completed the preliminary selection process and Steps 15 and 16 may be skipped.
- If the heating rating is equal to or larger than the requirement, no supplementary heater will be required and paragraph II-13 may be skipped. If the heating rating is smaller than the requirement, go to paragraph II-13.
- You should complete Steps 15 and 16 if the units in Step 14 are smaller or much larger than the requirement.

WORKSHEET PART III - SELECTION OF ECU (Page 2 of 2)

DUAL ECU'S

HORIZONTAL COMPACT

VERTICAL COMPACT

15. Nominal capacities (Btuh):

$$\frac{\quad}{(15a)} \times 2 = \frac{\quad}{(15b)}$$

$$\frac{\quad}{(15c)} \times 2 = \frac{\quad}{(15d)}$$

16. Actual ratings (Btuh):

Cooling: $\frac{\quad}{(16a)} \times \frac{\quad}{(16b)} = \frac{\quad}{(16c)}$

Cooling: $\frac{\quad}{(16d)} \times \frac{\quad}{(16e)} = \frac{\quad}{(16f)}$

Heating: $\frac{\quad}{(16g)}$

Heating: $\frac{\quad}{(16h)}$

17. Closest combination:

Cooling: $2 \times (16a) \text{ or } (16f) = \frac{\quad}{(17a)}$

OR $\frac{\quad}{(17b)}$

Heating: $2 \times (16g) \text{ or } (16h) = \frac{\quad}{(17c)}$

OR $\frac{\quad}{(17d)}$

INSTRUCTIONS FOR COMPLETING WORKSHEET

DUAL ECU'S

STEP 15 - NOMINAL CAPACITIES

- From Figure I-2, select the smallest pair of nominal capacities that satisfies the cooling requirement. Put these ratings in spaces (15a) and (15c). Multiply them by 2 and put the results in spaces (15b) and (15d). If the pair looks close, proceed with Step 16; if not, select another pair.

STEP 16 - ACTUAL RATINGS

- From Figure I-2, find the cooling and heating ratings for the vertical and horizontal ECU's picked in Step 15; enter these in spaces (16a), (16d), (16g) and (16h). Enter in spaces (16b) and (16e) the correction factor used in (14b) and (14e). Multiply and put the results in spaces (16c) and (16f).

STEP 17 - CLOSEST COMBINATION OF ECU'S

- If a pair of ECU's satisfies and is closer to the cooling requirement than the single units of Step 14, the pair, shelter space permitting, should be your preliminary selection. Heating consideration is the same as for Step 14.

SECTION III - MOUNTING THE ECU

III-1. Introduction

- This section suggests means for mounting the ECU's which you selected in Section II. The mountings presented here are structurally sound and fit a variety of applications.

- You will find that no single mounting concept is ideal for all aspects of an operational requirement; each has its good points and each has its drawbacks. As a consequence, you must clearly define your operational environment, establish your priorities, and then select the concept which comes closest to meeting your need or, conversely, creates the fewest problems. Further, your consideration of mounting concepts must be done in full coordination with all other equipment to be mounted or emplaced in the shelter.

III-2. Limiting Factors in Developing the Range of Mountings

There are a number of practical considerations which affect mounting options and narrow the range of possibilities.

- Side walls of all shelters are excluded from permanent exterior mounting. The maximum envelope dimensions that you must stay within for shipment preclude permanent exterior projections from the sides.

- Exterior permanent mountings on the end walls of all shelters, except the S250 and S280, also are precluded by the shipping envelope constraints.

- Permanent fixtures must be limited in expandable shelters. In one-side expandables, the expandable side and a portion of each end wall are excluded from any permanent fixture by the very narrow spacing between folded panels. Because of center of gravity considerations during lifting and moving, there should be restrictions also on the weight of equipment permanently installed on the nonexpandable side unless the shelter is permanently mounted on a truck or trailer. Both side walls and portions of both end walls in two-side expandables are excluded from use for permanently mounted equipment.

- Exterior mounting of the ECU on the entrance end of the S280 is to be avoided because of the potential requirement for a protective entrance (PE). (There are instances, however, where both the PE and ECU have been accommodated on the entrance end, but this requires a special design for the end panel to move the door from the middle to one side.)

- Permanent end-wall mounting of any ECU heavier than the 36,000 Btuh units is risky because of the limited strength of the shelter wall panel, which could fail during road or rail movement.

- All mountings, when in shipping configuration, must withstand railroad humping loads (up to 6 G's in the vertical and lateral directions and 10 G's in the longitudinal direction (from Reference 6)) and survive in the

nuclear conditions described in Section VII. These requirements have resulted in much heavier mountings than would be required for a shelter which can remain static and not be subjected to tactical requirements.

- The requirement for setup or takedown-packup to be accomplished within 30 minutes by two men with little or no mechanical lifting assistance dictates:

- Permanent mountings where practicable: slide-in/slide-out and inside-fixed or exterior-fixed wall mountings.

- The exclusion of mountings which require manual lifting of the ECU more than a few inches off the ground in order to mount it.

- That remote mountings be designed as self-contained units. The ECU should be transported on its mounting pallet so that only positioning relative to the shelter, connecting, and turning on are all that are required upon arrival at the operating site. All hardware necessary for putting the unit into operation must accompany the ECU and be readily available and accessible. The possibility of separation or loss during storage, shipment, and use must be at a minimum.

- The mounting should permit ready access for routine servicing and minor maintenance without removal of the ECU from its position. If slight shifting must be done, it should be possible without the need for mechanical lift assistance. This requires that both sides, front, back, and top be exposed or easily exposable.

III-3. Recommended Match-Ups

To assist you in narrowing your considerations, a table of recommended shelter-ECU match-ups is shown in Figure III-1. Types of mounts suitable for these match-ups are discussed in paragraphs III-4 through III-7, below.

III-4. Retractable Mounting

- Description. The distinguishing feature of the retractable mounting is its ability to move out of and back into the shelter through a hole in the shelter wall. In the design presented here, this movement is made possible by the commercially available supporting ball bearing slides, or tracks. The recommended position of the mount is at floor level where it requires the least amount of space-consuming bracing and reinforcing to withstand the dynamic loading of rail shipment. A type of retractable mount is illustrated at Figure III-2; a design drawing is at Appendix III-1.

- Benefits.

- In concept, the retractable mount is the best system for the shelters of this handbook in non-CB and non-nuclear environments. It permits you to keep the noise and heat outside the shelter during operation while allowing for rapid deployment. In non-CB and non-nuclear environments, the ECU can be retracted for redeployment with little time and effort and then pushed out again into operating position upon arrival at the new site.

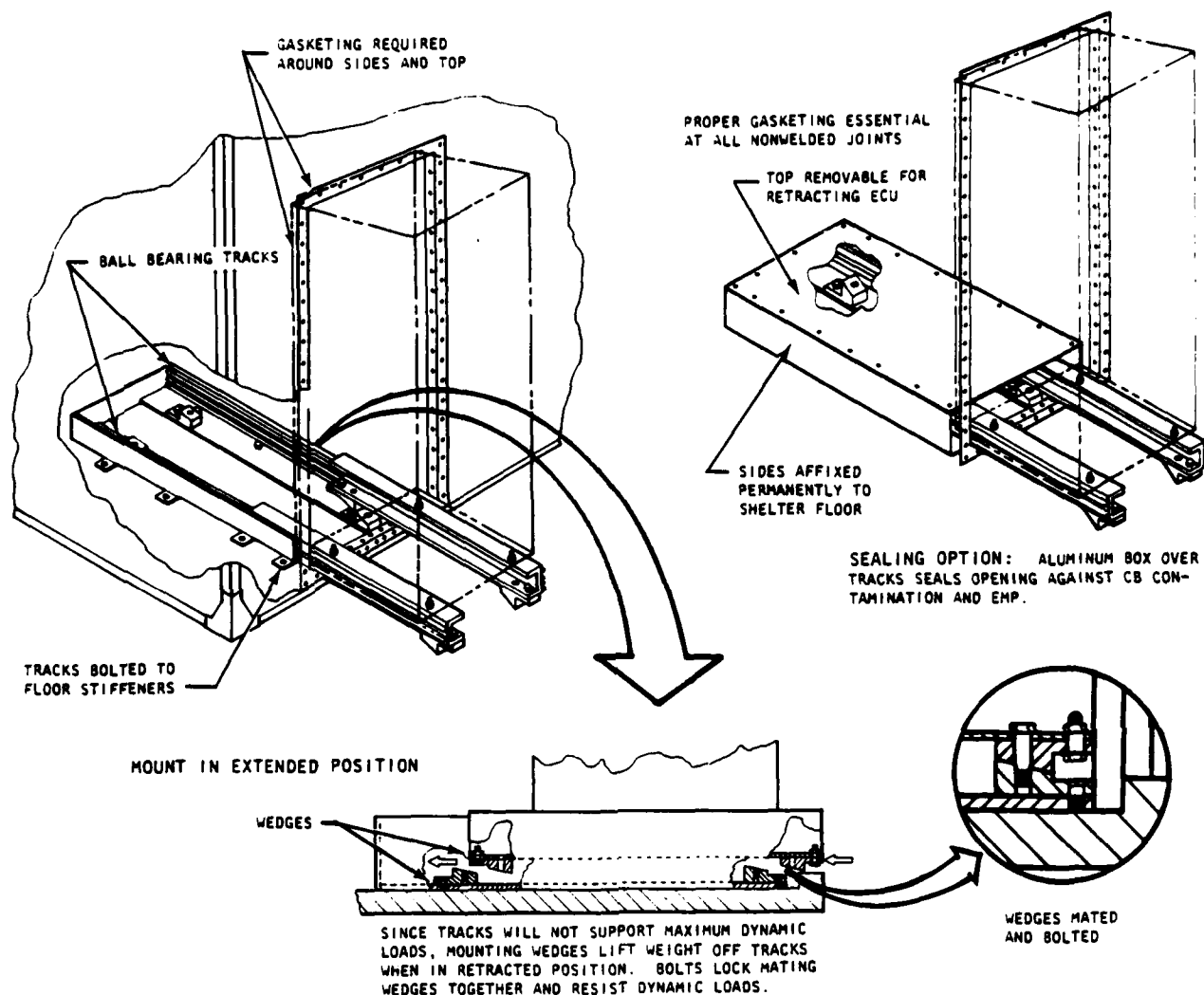
SHELTER	HORIZONTAL ECU	VERTICAL ECU	MOUNTING POSITION OPTIONS
NONEXPANDABLE			
S250		6,000 9,000	Rear ² exterior wall Rear exterior wall
S280	9,000 (Single or Double) 18,000 (Single or Double) 36,000 All above, plus 60,000	6,000 9,000 18,000 36,000 All above, plus 60,000	Front ² or rear exterior wall Front or rear exterior wall Front exterior wall ³ Front exterior wall ³ Front exterior wall Front exterior wall ³ Ground: remote or flush; entry through any wall Retractable: any wall
ISO, Army, GP	Same as S280		Any wall: mount should be retractable, fixed interior or ground type
Navy	Same as S280		Any wall: mount should be retractable, fixed interior or ground type
EXPANDABLE			
All	36,000 and 60,000 (Below 36,000, vertical ECU's present a more suitable matchup)	6,000, 9,000 and 18,000 (Above 18,000, horizontal ECU's present a more stable package and a smaller envelope)	Remote ground mount with flexible ducting Flush ground mount with boot to eliminate flexible ducting

¹See Figures I-1 and I-2

²Rear - shelter entrance end
Front - end opposite from shelter entrance

³Fixed or retractable mount

Figure III-1. RECOMMENDED SHELTER-ECU MATCHUPS ¹



Major actions to place into operation: Remove plug from wall opening; push ECU into operating position; attach bracing as required; place cover plate over tracks inside shelter (for sealing); attach power and control cables; attach any ducting required; start ECU.

CHARACTERISTICS OF RETRACTABLE MOUNTING

- ECU mounted on ball-bearing slides. For shipping, ECU locked in retracted position inside the shelter (sketch illustrates concept). For humping, ECU also requires bracing at top. Bolthole in upper rear of ECU provided for this purpose. For operation, ECU pushed through opening in shelter wall into extended position.
- To withstand nuclear overpressure in extended position mount and ECU require removable external bracing against movement in all three planes (not shown on sketch).
- Mounting shown uses vertical ECU which generally is a more suitable configuration. Mounting is adaptable to a horizontal ECU.

Figure III-2. MOUNT FOR RETRACTABLE ECU

●● When retracted, this mounting method leaves no significant exterior projections to violate the shipping envelope. This benefit is most notable with the shelters larger than the S250 and S280. (The S250 and S280 can fit into a shipping container with their ECU's still mounted on the front end).

●● The ECU is protected during shipment since it is inside the shelter.

● Problems.

●● The stringent sealing requirements for an NBC (including EMP) environment are very difficult to meet and to maintain with a retractable mount. The irregular surfaces around the tracks supporting the ECU constitute an exceptionally difficult interface joint to seal. A concept for this is shown on Figure III-2. Reference 35 shows a concept for closure used with the Navy ECU's. Further, when seals must be repeatedly broken and re-established, there is a serious doubt that they will continue to be effective in:

-- Maintaining the positive air pressure necessary for CB protection without an undue loss of air from leakage and the resultant increased demand on the ECU and the gas particulate filter unit (see Section V).

-- Sealing against CB and radioactive contaminants during brief moments when outside pressure may be greater than inside pressure. Such reverses in pressure may be from a number of causes to include a gust of wind or a passing truck.

-- Maintaining the seal against EMP, which is critical if solid-state equipment is to survive.

●● The best ball bearing tracks available are strong and durable but, when extended, cannot be relied upon to withstand significant dynamic loading while supporting the weight of the ECU. Therefore, to survive significant nuclear overpressure (see paragraphs VII-2 and -3), the mounting would need reinforcing with outside bracing comparable to the wall mount designs presented in paragraph III-6. Since projections outside the shipment envelope are unacceptable, the bracing would have to be removed for transit, stowed during transit and reinstalled upon setup. This would detract from the quick setup and takedown benefits of the retractable mount. Further, there would be little gain, if any, in survivability since the current shelter, itself, is rather weak in this respect (see paragraph VII-2).

●● There is no gain in interior space when the mount is in the extended position. The area vacated by the ECU when it is extended (and into which it retracts) is not available for other uses since this area must remain clear to prevent blocking the air passage (unless detachable ducting is provided, which would further complicate the takedown and setup process by adding to the number of pieces to be disconnected, stowed, and reconnected).

●● Structurally, the best position to place the retractable mounting is on the floor. The best position from an air distribution viewpoint is near the ceiling.¹ The dynamic loading of railroad humping would make a structure for putting the ECU near the ceiling rather space-consuming. (Note comment on use of equipment racks in paragraph III-5, below.) The problem could be overcome by use of a riser duct from the air supply outlet of the ECU to a point near the ceiling. But this would require space (up to 8 inches from the wall and as wide as the ECU air supply discharge). Also, as noted above, ducting would complicate the takedown and setup process.

●● The ECU should not be retracted into the shelter following a CB attack until it is decontaminated.

III-5. Inside Fixed Mounting

● Description.

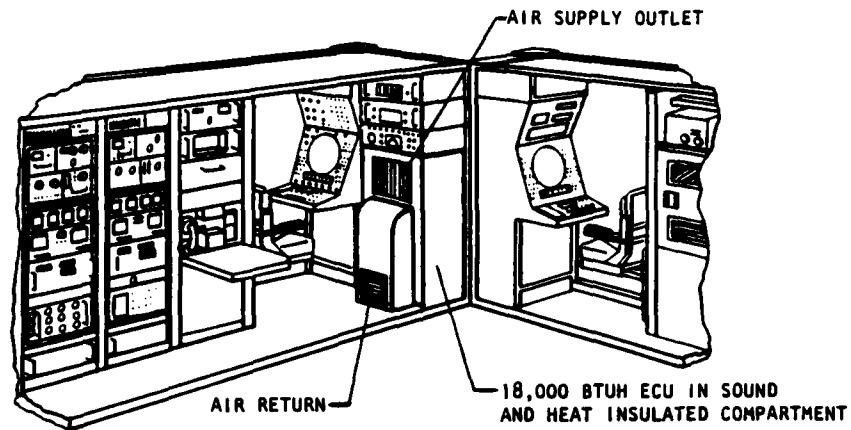
●● For floor mounting, the ECU is fixed into its place firmly enough to withstand the rail shipment dynamic loadings and is insulated to reduce both heat and noise (the heat being that which radiates from the ECU housing). The rear of the ECU faces outside through a hole in the shelter wall so that air used for cooling the condenser is discharged directly outside without entering the shelter compartment.

●● Since the mounting bolt spacing of the ECU probably will not coincide with the floor stiffener spacing, a plate or beams will have to be used to span and be bolted to the stiffeners. The ECU can then be bolted to the plate or beams. It is advisable also to use a reinforcing back plate beneath the floor, on the outside, which can be connected to the base plate or beams by bolts through the shelter floor. The Base Civil Engineer should be able to provide the engineering for this relatively uncomplicated requirement. One way to deal with the problem of noise and heat from the inside-mounted ECU, and at the same time provide the vertical ECU with the necessary bracing against overturning, is to fabricate a rigid, insulated enclosure for the ECU (note Figure III-3). The enclosure would attach to the shelter floor and wall and be removable to permit access to the ECU for repair and maintenance.

●● Mounts near the ceiling would require structure inside the shelter which, depending upon its design, may reduce space for other purposes. A supporting structure, such as equipment racks of the type provided by shelter manufacturers, if adequately anchored, can support the ECU near the ceiling and might permit better space utilization by allowing the space beneath the ECU to be used for other purposes.

¹Provided there are no obstructions to block the air flow (see Section IV), cooling can probably be accomplished in the shelters addressed by this handbook with a floor-mounted ECU, although somewhat less efficiently and effectively. Because of their height, the vertical ECU's are more suited to floor mounting than are the horizontal models and can probably be used satisfactorily without ducting. A floor-mounted horizontal ECU, on the other hand, should probably have its supply ducted to near the ceiling.

VERTICAL ECU WITH DUCTING TO SEPARATE AIR SUPPLY AND AIR RETURN



VERTICAL ECU WITH AIR SUPPLY DUCTED TO CEILING LEVEL OUTLETS

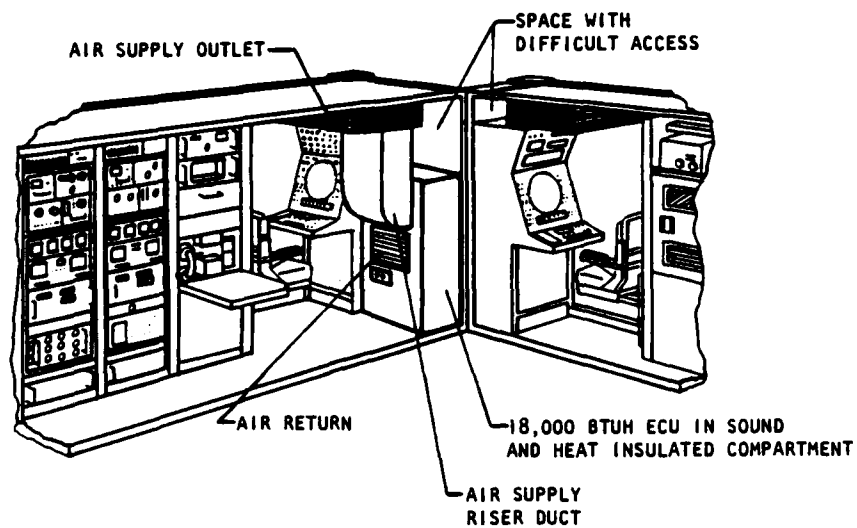


Figure III-3. INSIDE MOUNTED ECU'S ILLUSTRATING CHARACTERISTIC SPACE REQUIREMENTS

• Benefits

•• The ECU is fixed and braced in place and ready to turn on almost immediately upon arrival at the operating site. Further, there are no requirements for you to remove hardware in preparation for a move, to stow it during transit, and to replace it upon arrival, so takedown and setup times are practically nil.

•• Sealing is comparatively easy since gaskets are compressed between the relatively even surfaces of the rim of the ECU's rear face and the frame around the hole in the wall panel. Additionally, the seals should be more effective than with most other mounts since there is no requirement to break them for moves; the floor mounting should permit maintaining a rigid joint with a constant pressure on the seals.

•• The ECU is protected at all times to the same degree as other interior-mounted equipment.

•• This is a less expensive and more quickly installed mounting than all others considered.

• Problems

•• Military ECU's are designed primarily for outside installation, so the condenser sections of the ECU's are not insulated. As a consequence, they are heat producers in summer and cold producers in winter. Further, they are noisy, especially the vertical configurations, although, newer models have been improved somewhat in this respect. Adequate insulation can reduce the heat problem to a manageable level but may help less effectively with noise. A good, solid job of mounting should be some help with vibration and noise.

•• For structural reasons, the shelter floor is the best place to mount the ECU, but this position is not the best for air distribution.¹ Adequate bracing inside the shelter, to support the ECU near the ceiling and meet the railroad humping load requirement, would be very space consuming and is not recommended unless standard equipment racks can be made suitable. The ducting necessary to raise the air supply outlet from the floor to the ceiling would also consume space. To rise vertically from the ECU air supply discharge, the ducting would be 20 to 30 inches from the wall (a little more than the distance from front to back of the ECU) and, unless adjacent equipment can lend support, would be free standing and require special bracing. Some appreciation of the space requirement may be gained from the sketches in Figure III-3.

•• Access for maintenance and repair can become a problem unless care is taken in locating adjoining equipment. There must be clearance for hands and the use of appropriate wrenches in demounting and remounting the ECU.

¹Ibid.

III-6. Outside Wall Mounting

• Description. The ECU is wall-mounted outside the shelter on a frame affixed to the end panel of the shelter. The conditioned air supply and return face into the shelter through a hole in the wall. The mountings are designed to withstand railroad humping; an incidental benefit is an ability to survive an estimated nuclear free field overpressure of 4 psi. Since the structural design of shelter wall panels, according to the leading manufacturers, varies widely even within the same shelter type, the design cannot rely solely on end panel strength. Instead, it transfers a major portion of the load from the end panel to the corners and into shear stresses in the side and roof panels. (The thin-skinned sandwich panels are much stronger in shear than in moment.) Sample design computations are included in Appendix III-2; design drawings are at Appendix III-3. You can find wall mountings illustrated in Figures III-4 and III-5.

• Benefits

•• There is no requirement for setup and takedown for relocations.

•• Noise and radiated heat are outside the shelter.

•• There is a space saving by not having the ECU and its mounting structures inside the shelter. This saving is reduced somewhat, however, by the need to keep the area in front of the ECU open and permit proper air flow.

• Problems

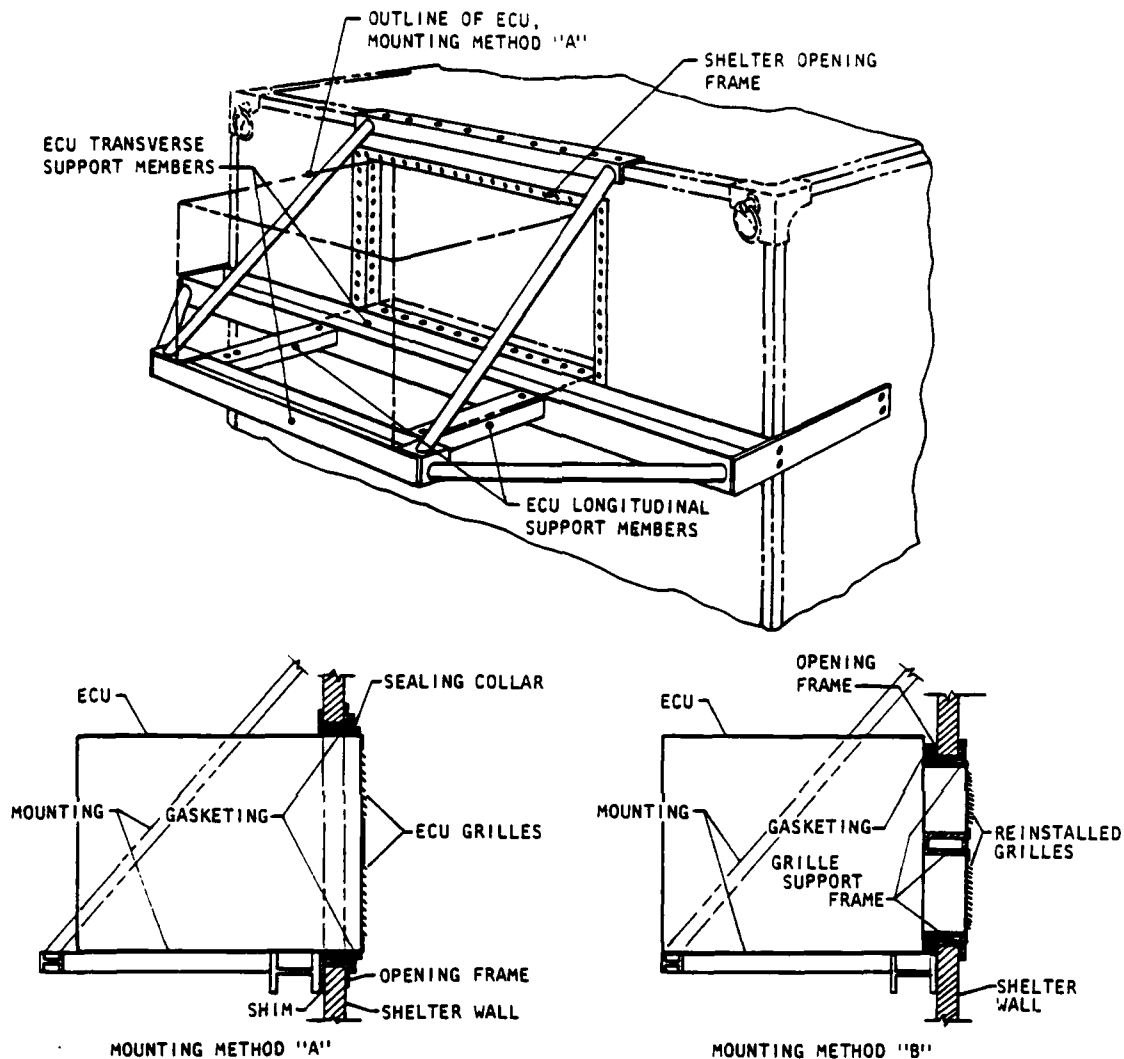
•• The use of the outside fixed mounting is limited to the S250 and S280 shelters. These mounts would be applicable also to other shelters of similar width if their use were not precluded by the shipping envelope constraints.

•• Because of their exposed position, the outside mounted ECU's are subject to damage by flying fragments as well as nuclear blast and thermal effects.

•• The outside wall mounts assume that the shelter will be truck-mounted and therefore are designed to overhang the truck cab. The designs are intended to allow adequate clearance between the mounting frame and the truck cab. However, the height of the cab top above the truck bed can vary several inches not only between truck types but also within the same type. Therefore, the vertical distance between the cab top to the bed level must be determined and checked against the mounting design for each truck used to see whether the mount will clear the cab or whether the shelter should be raised by blocking.

III-7. Ground Mounting

• Description. The two types of mountings described below should satisfy nearly all ground mounting requirements.



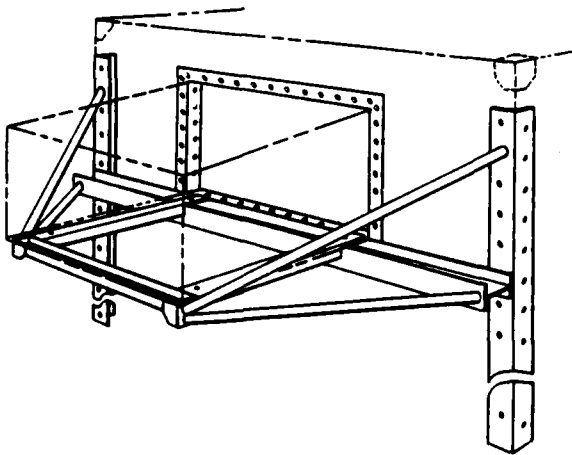
MOUNTING METHOD "A"
ECU fits through opening into shelter. This is simpler of two methods but it is a little more difficult to seal.

MOUNTING METHOD "B"
ECU is completely outside shelter. Supply and return grilles and control panel are removed and reinstalled onto a grille support frame which must be fabricated. Grille support frame must include ducts to keep supply and return air separated in space between ECU and remounted grilles.

CHARACTERISTICS OF FIXED MOUNTINGS

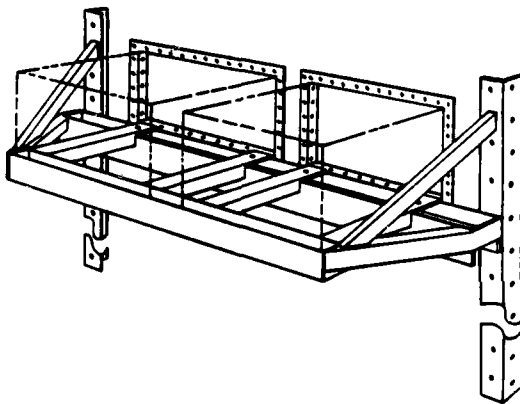
- Permanently attached to shelter; permits shipping shelter with ECU in place (ECU mounted using normal boltholes in bottom of unit).
- Designed for rail humping loadings of 6G in vertical and transverse directions and 10G in longitudinal direction.
- Designed for nuclear overpressures up to 4 psi.
- Fabricated from standard aluminum extruded shapes or from shapes built up from aluminum sheets. Welded construction.

Figure III-4. TYPICAL WALL MOUNTING



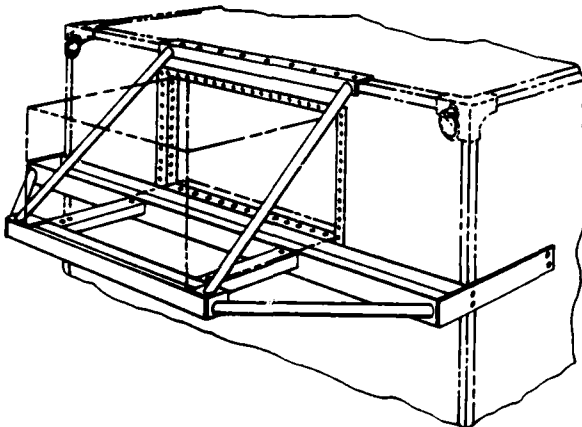
WALL MOUNT #1

Applicable
ECU: 9,000 Btuh
18,000 Btuh
Approximate
Weight: 113 pounds
Design
Drawing: Appendix III-2
Figure III-2-1



WALL MOUNT #2

Applicable
ECU: (2) 9,000 Btuh
(2) 18,000 Btuh
Approximate
Weight: 118 pounds
Design
Drawing: Appendix III-2
Figure III-2-2



WALL MOUNT #3

Applicable
ECU: 36,000 Btuh
Approximate
Weight: 133 pounds
Design
Drawing: Appendix III-2
Figure III-2-3

Figure III-5. WALL MOUNTINGS FOR HORIZONTAL ECU

●● Remote mounting. The ECU is mounted and braced on an aluminum frame pallet, see Figure III-6. Also on the pallet is space for stowing the hardware necessary to put the ECU into operation. The ECU is shipped on its mount, separate from the shelter. When tied down to prevent tipping, the mount is designed to survive rail hump loadings as well as the nuclear overpressure up to 4 psi. (Sample design computations are included in Appendix III-4 and a design drawing is at Appendix III-5.) In operation, the mount is located 4 to 8 feet from the shelter and the conditioned air is carried to the shelter by flexible ducting.

●● Flush mounting. The main conceptual difference between this and the remote mount is that the flush mounting is almost touching the shelter as illustrated in Figure III-7. Shelter and ECU are connected by a short, heavy-duty boot made of high-heat-resistant material. The boot is accorded to absorb a small amount of independent movement between the shelter and ECU. It is strong enough to provide a degree of support to the ECU so that it can use a simpler mounting than that required of the remote concept. The mounting illustrated in Figure III-7 is a suggested type but any mounting which would hold the ECU at the desired level and prevent its tipping over should be acceptable.

● Benefits

●● Remote mounting.

-- Since the conditioned air supply and return are carried in 10-foot-long flexible ducts, this mounting method offers the most flexibility of all the mounts for locating the supply and return opening(s) in the shelter wall. You may locate them separately or together, select a position to avoid obstructions and prevent a short circuit (see definition in Appendix A-1), and place the openings to make most effective use of available air passages inside the shelter, thus reducing the space that must be dedicated solely to this purpose.

-- The sealing of the interface between the ECU and the shelter is comparatively simple to achieve and maintain.

-- There is practically no stress on the wall panel from the mounting.

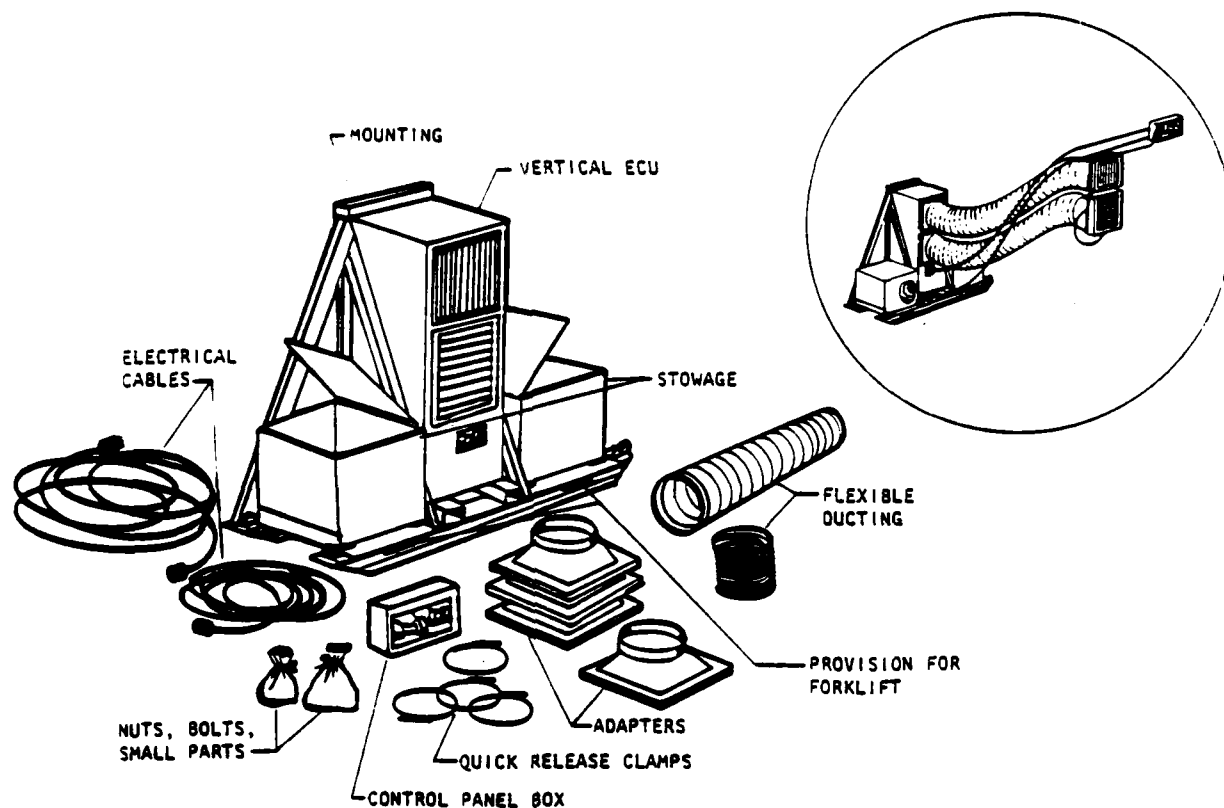
-- The remote mounting can be used with any size ECU and with any shelter.

-- There is full accessibility for maintenance and repair of the ECU.

-- The shelter is isolated from the vibration and noise of the ECU.

●● Flush mounting.

-- Sealing the ECU-shelter interface is a comparatively easy task since fairly even surfaces meet each other and gaskets can be uniformly compressed.



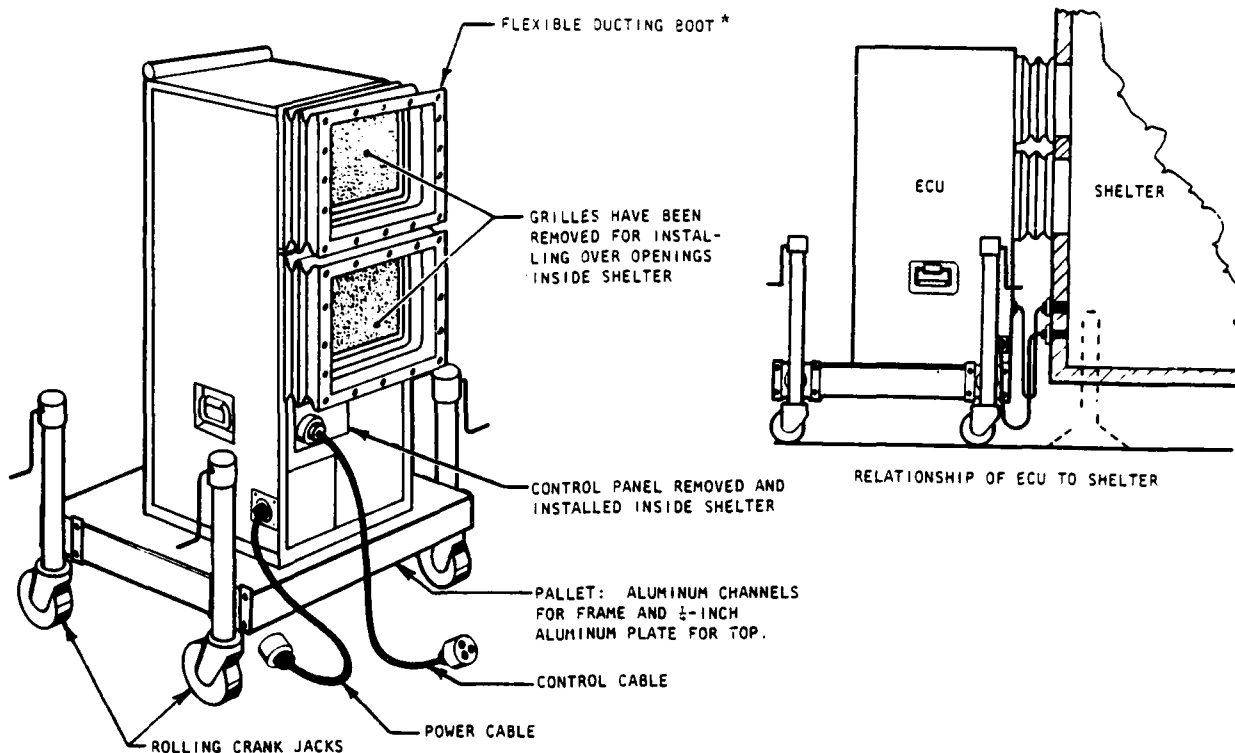
REMOTE MOUNTED ECU WITH ESSENTIAL ACCOMPANYING PARTS

Major actions to place into operation: locate and level mount, remove supply and return grilles from ECU and install on grille support frame (permanently installed on inside of shelter), mount control box in shelter, install adapters and flexible ducting, connect power cables.

CHARACTERISTICS OF REMOTE MOUNTINGS

- Located away from shelter.
- ECU bolted to skid-mounted pallet, using normal ECU boltholes, for shipment and operation.
- Includes stowage for all necessary hardware.
- Designed for rail humping loadings of 6G vertically and transversely and 10G longitudinally.
- Designed for nuclear overpressures up to 4 psi.
- Fabricated from standard aluminum sheets and extruded shapes. Welded construction.

Figure III-6. *TYPICAL REMOTE GROUND-MOUNTED ECU*



*A SOURCE FOR THIS KIND OF BOOT IS:

THERMOID DIVISION
H. K. PORTER COMPANY, INC.
1101 PORTER BUILDING
PITTSBURGH, PA 15219

Major actions to place into operation: Remove grilles from ECU; attach boot to ECU; attach power cables; push ECU into position close to shelter; attach necessary gasketing; attach boot to shelter; attach necessary filters; attach grilles to opening inside shelter; attach necessary tiedowns.

CHARACTERISTICS OF FLUSH MOUNTING

- ECU mounted on simple pallet to provide stability for shipment and operation. For railroad shipment and when nuclear overpressure loadings are expected, tiedowns, from the top, should also be provided. Pallet has light duty, rolling crank jack (several types are commercially available) on each corner for adjusting height up to 12 inches and for leveling. Wheels on jacks permit short moves at very slow speeds and manually shifting position of unit.
- ECU located approximately 6 inches from shelter and attached to shelter by custom made, commercial heavy, flexible, high heat ducting, or boot. Boot has metal flanges bonded to ducting. Small access space between ECU and shelter dictates that flange and bolt holes be accessible from the inside of boot. Boot is connected to ECU first. ECU is then pushed against shelter. Access to bolts is from inside of shelter through hole in wall panel to inside of boot.
- Suggested means of transporting boots, bolts, and wrench is canvas pouch, or pouches, which can be strapped to ECU.
- Vertical ECU is shown in illustration but concept is adaptable to horizontal units.

Figure III-7. TYPICAL FLUSH GROUND MOUNTING

-- The short boot which connects the ECU and the shelter is relatively hard. It is much shorter and much tougher than the long flexible ducting of the remote mount. Also, it is between the ECU and the shelter and thereby somewhat shielded from thermal radiation.

-- There is no constraint on matching ECU's and shelters.

-- During normal operation, there is little stress on the shelter panel from the mounting.

-- The shelter is separated from the ECU by the length of the boot (approximately 6 inches). This serves to isolate the shelter from the vibration and noise of the ECU.

- Problems

- Remote mounting.

-- The ECU and ducting are vulnerable to fragments, blast pressures, and thermal radiation; the ducting should not be expected to survive.

-- The weight of the ECU and the mount requires mechanical lifting equipment and transporting equipment to move the system to the site and to place it where it will be used. If materials handling equipment, cranes, or wreckers are available, this is no problem. A system shipped by sea would require transport to move it to its site and plans would probably be in place for this. One shipped by air may require a dolly or other means of short-range transport to move it from the aircraft to its on-base site. Long distances would require major transport means in any event.

- Flush mounting.

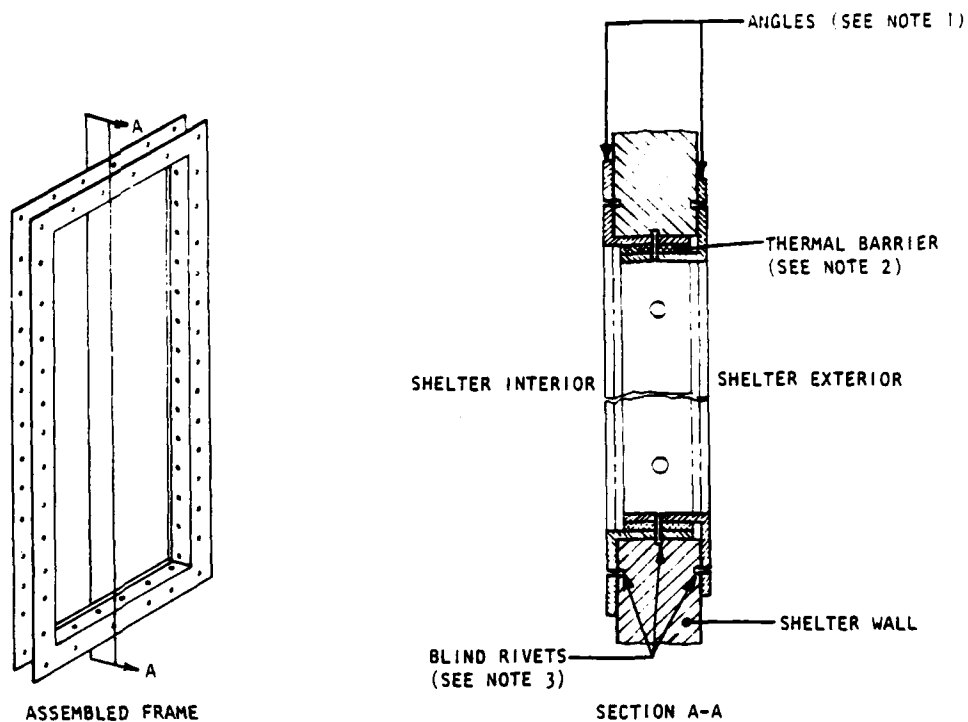
-- Although less vulnerable than the remote mounting, the fact that the ECU is in the open renders the flush mount, also, susceptible to damage by fragments, blast pressures, and thermal radiation. However, the boot duct should survive in cases in which the ECU and shelter survive.

-- The weight of the ECU presents the same requirement for moving and handling as does the remote mounting.

●● Because of their height, both mounts are subject to tipping when hit by the blast wave or subjected to railroad humping. They should therefore be tied down during both movement and operation.

III-8. Frames

For all mounts, the necessary holes or openings in the walls must be adequately framed both to restore and reinforce the strength and rigidity of the panel and to protect the edges of the hole. A framing concept which is commonly used and which has proved to be satisfactory is illustrated on Figure III-8. The frame can be modified in size and strength to accommodate having other structural members bolted to it.



NOTES:

1. ALUMINUM ALLOY 6061-T6: EXTRUDED OR FABRICATED ANGLES, MINIMUM 1/8 IN. THICK. LEG LENGTHS TO ACCOMMODATE SHELTER WALL THICKNESS AND ANY STRUCTURAL ATTACHMENTS (E.G., MOUNTING FRAMES).
2. THERMAL BARRIER, 1/8 IN. THICK:
 - LAMINATED PLASTIC - MIL-P-15035, TYPE FBM OR
 - TEFLON STRIP - MIL-P-22242 OR
 - PLYWOOD, EXTERIOR TYPE, COMMERCIAL STANDARD PS-1-74
3. RIVETS SHOULD BE DIPPED IN CONDUCTIVE SEALANT PRIOR TO INSERTING INTO HOLES.

Figure III-8. SHELTER OPENING FRAME

III-9. Summary

For convenience, a Table of Considerations for Selecting ECU Mountings, which summarizes the discussions of paragraphs III-2 and III-4 to III-7, is included at Figure III-9.

CONSIDERATION	EXTERIOR FIXED WALL MOUNTINGS	RETRACTABLE & FIXED INSIDE MOUNTING	GROUND MOUNTINGS (REMOTE & FLUSH)
Which shelters are applicable?	S250 and S280 only (all others precluded by shipping constraints).	All nonexpandable shelters (no permanent fixtures in walls of expandable shelters).	All shelters.
What ECU sizes can be mounted?	Up to: Two 18,000 Btuh, or One 18,000 Btuh plus 1 GPFU, or One 36,000 Btuh	Up to one 36,000 Btuh per mounting. Vertical ECU's present better space utilization in most cases.	No restrictions. (But for ECU's of 36,000 Btuh and above, horizontals present a smaller envelope. Verticals are preferred below 36,000 Btuh.)
Any restrictions on mounting locations?	<ul style="list-style-type: none"> ● Restricted to: <ul style="list-style-type: none"> - Rear end wall of S280. Front (entrance) end precluded by need to preserve option to use CB protective entrance. - Front (entrance) end of S250. ● Shipping considerations preclude use of: <ul style="list-style-type: none"> - All side walls of all shelters. - All shelters larger than S280. - All expandable shelters. 	<ul style="list-style-type: none"> ● Should be restricted to floor level only. ● All two-side expandable shelters cannot use mounts which are not dismantled before shelter is prepared for movement. 	No restrictions.
What clearances are required inside shelters?	Sufficient to prevent blocking of air supply and return flow. Refer to Section IV of this handbook.	Requires space for entire ECU, plus riser air duct; also space sufficient to prevent blocking of air supply and return flow (see Section IV).	Sufficient to prevent blocking of air supply and return flow (see Section IV). Supply and return can be close together or separated when flexible ducting is used for carrying air to shelter.
Any exterior ducting required?	None required.	None required.	Normal remote mounting requires flexible ducting. The ground flush mounting uses a boot which allows ECU virtually to be attached to shelter yet permits small independent movement and isolates shelter from ECU vibration.
What set-up tasks are required at the operational site?	None.	Retractable: Unplug wall opening; remove bolts, emplace ECU in out position; affix external bracing, install air duct connections, seal around opening. Fixed Inside: Unplug wall opening.	Minor leveling of ECU pallet, unplug wall opening(s), connect adapters and ducting, connect control cables, and connect power cables. (Assumes pallet-mounted ECU was satisfactorily located when delivered. ECU and pallet can be manhandled for small adjustments in position.)

Figure III-9a. TABLE OF CONSIDERATIONS FOR SELECTING ECU MOUNTINGS
(Continued on next page)

CONSIDERATION	EXTERIOR FIXED WALL MOUNTINGS	RETRACTABLE & FIXED INSIDE MOUNTING	GROUND MOUNTINGS (REMOTE & FLUSH)
How is the access for servicing and minor repairs?	Good.	Retractable: Good. Fixed Inside: Good to poor.	Excellent.
Can mounting, with ECU affixed, withstand shipping?	Designed to withstand rail humping loadings (6 G in vertical and transverse directions and 10 G in longitudinal direction). NO TESTING HAS BEEN DONE.	Retractable: When in retracted position only. Fixed Inside: Proper floor mounting should stand up to hump loads.	Mounting pallet is designed to withstand rail humping loadings with ECU in mounted position. NO TESTING HAS BEEN DONE.
What is extent of nuclear hardening?	Overpressure up to 7.3 psi. ECU may be vulnerable to fragments. NO TESTING HAS BEEN DONE.	Retractable: Can withstand only in retracted position (if shelter has been hardened). NO TESTING HAS BEEN DONE. Fixed Inside: Same as above.	Mounting will take 7.3 psi with ECU on it but will need anchoring to prevent moving or tipping over. Flexible ducting is extremely vulnerable. Boot used with flush mounting is expected to be equal to mounting. NO TESTING HAS BEEN DONE.
What is difficulty of sealing the ECU openings in the shelter against air loss and NBC contamination?	Moderate.	Retractable: High. Fixed Inside: Moderate.	Minimal.
Is transportation separate from shelter required?	No. ECU and mount are permanently attached to shelter.	No. ECU and mount are permanently attached to shelter.	Yes. ECU is separately mounted and transportation arrangements for it are required. This includes long distance and short distance moves. Also, mechanical help for loading and unloading from transporting vehicle is required.

Figure III-9b. TABLE OF CONSIDERATIONS FOR SELECTING ECU MOUNTINGS

SECTION IV - DISTRIBUTING AIR IN THE SHELTER

IV-1. Introduction

• You will find that most heating and air conditioning manuals are aimed at buildings requiring considerably more complex air distribution systems than do tactical shelters. Fortunately, most of the factors which impact heavily on air flow in long, complex systems have drastically less impact on the types of short, compact systems of concern here. Therefore, for these small systems, simplifications can be introduced to permit easier and quicker design without appreciably degrading either the design or the effectiveness of the system.

• If you encounter more complex problems than the ones addressed here, you should consult appropriate handbooks (References 4, 7, and 19, for example) or an air conditioning engineer for the needed assistance.

IV-2. Free-Flow or Ducted Distribution?

• There are two ways in which you can distribute the air within a shelter. One is free-flow, that is, direct discharge of the conditioned supply air into the shelter with sufficient velocity and direction so that the air, in effect, distributes itself. The other way is to carry the air through ducts directly to the point or points where it is needed. In a combination of these two methods, you may duct the supply, only. It is very unlikely that you would need to duct the return in small shelters.

• Free-flow distribution will be adequate in most cases covered by this handbook and you should use it wherever possible. It has the advantages of being cheaper, quicker, and easier to install than ducted distribution and it takes up less space inside the shelter.

IV-3. Planning the Distribution System

• Obtain scale drawings of the plan and elevation of the shelter interior. Then follow the planning steps on the Air Distribution System Planning Instructions, pages IV-2 through IV-4.

• In one system or another, you will certainly encounter the need to change the duct's cross-sectional dimensions, change direction, or direct some of the air to intermediate points, and maybe all of these. These changes need not have a great impact on your system effectiveness if they are handled properly. If and when you encounter these needs, refer to paragraphs IV-4 through IV-7 for advice.

• When ducting is to be used for both cooling and heating, it is normally designed for cooling with the knowledge that it will work also for heating. Auxiliary heaters in a shelter will probably be unducted or, if ducting is necessary, separately ducted.

AIR DISTRIBUTION SYSTEM PLANNING INSTRUCTIONS

STEP NO.	STEP DESCRIPTION AND EXPLANATION	COMPLETED
	Steps 1 thru 17 are in Section II - Selecting the ECU	
18	<p>Determine what needs cooling:</p> <ul style="list-style-type: none"> • Personnel • Equipment • Both 	
19	<p>Accurately locate on the scale drawings personnel stations and all installed equipment, cabinets, or other objects which might cause an obstacle to straight air flow. Identify the position of electrical equipment.</p>	
20	<p>Determine where the ECU supply and return will be. You may not have much choice in this; the location of a wall-mounted ECU is dictated largely by the shelter wall structure and the mounting structure design. The ducted supply and return from an ECU on a remote mount provide more flexibility for locating the entry into the shelter. But even here, you may find yourself restricted by the arrangement of interior-mounted mission equipment. If you have a choice:</p> <ul style="list-style-type: none"> • Position the supply and return to avoid a short circuit¹. • Locate the supply so that the air stream is afforded a straight path to the primary area to be cooled. • Locate the supply so that the conditioned air reaches personnel stations first and electrical equipment second. • For horizontal ECU's, locate the supply entry into the shelter in the upper part of the wall. If the ceiling is free of obstructions, a location near the ceiling should be selected. If there is an obstruction on the ceiling, the supply should be lowered to where a straight air stream will miss the obstruction. In most cases the supply air outlet of a vertical ECU mounted at floor level will be high enough to permit free flow distribution without ducting unless there is an obstruction to proper flow. The location of the return is less critical but should not be blocked or positioned to cause a short circuit (see Figure IV-1). It is desirable that the return be in the lower part of the wall, even near the floor if this is an easy option. 	
	<p>¹See definition in Appendix I-1. A short circuit can defeat your system so avoiding it is important.</p>	

Clearance for Air Return

The following is a rule of thumb and not a hard-and-fast requirement. You may vary from it if the equipment in the shelter cannot be arranged to permit the recommended clearances. But you must keep in mind that the more you squeeze the air flow clearances, the greater the risk to the effectiveness of the environmental control system.

The clearance (d_c) in front of return intake of the ECU should be at least 2 inches or that necessary to provide a cross-section of air flow equal to twice the area of the ECU return intake opening, whichever is greater.

Example:

A = Area of ECU air return intake opening
 = 15 in. x 16 in. = 240 sq in.
 w_c = Width of clearance = 16 in.
 h_c = Height of clearance = 30 in.

FIND: Required depth of clearance, d_c

$$2A = d_c (2h_c + w_c)$$

Notice that since obstruction is sitting on the floor, air flow is around three sides only.

$$d_c = \frac{2 \times 240}{2(30) + 16} = 6.3 \text{ inches}$$

NOTE: If the air flow from the sides of the ECU is lessened by reducing the clearance or adding more obstructions, the more will be the air that must come over the top of the obstruction. This path will impinge on the flow space of the air from the supply outlet and create conditions that could result in a short circuit. If this becomes a problem, the supply air outlet should be relocated by ducting.

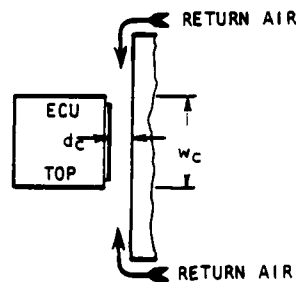
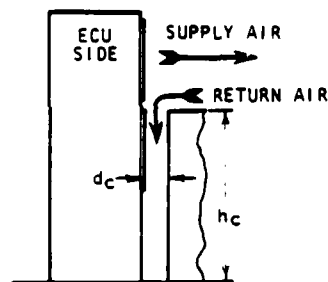
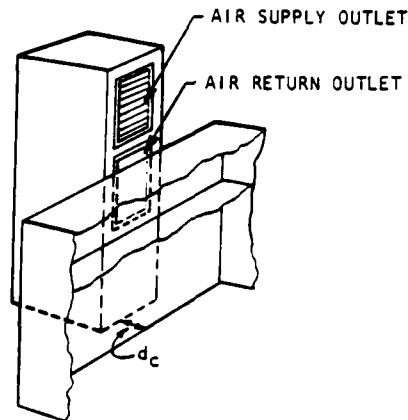


Figure IV-1. RETURN AIR CLEARANCE

AIR DISTRIBUTION SYSTEM PLANNING INSTRUCTIONS

STEP NO.	STEP DESCRIPTION AND EXPLANATION	COMPLETED
21	Accurately locate on the drawings the conditioned air supply and return outlets.	
22	Determine by using the drawings if there is a direct, unobstructed view, at least as wide as the supply outlet, from the air supply to points to be cooled. If not, an unsatisfactory condition for free-flow distribution exists. See Step 25.	
23	Determine by using the drawings if a short circuit condition exists or is likely to exist. A good rule of thumb to follow is: if it seems likely that there will be a short circuit, assume there will be. If there seems to be a short circuit condition, an unsatisfactory condition for free-flow distribution exists. See Step 25.	
24	Determine if free-flow air will pass heat generating electrical equipment enroute to personnel. If so, multiply the wattage of the equipment by 3.4 Btuh per watt. If the result is 35% ¹ or more of the ECU rated cooling capacity, an unsatisfactory condition exists for free-flow distribution. See Step 25.	
25	<p>If all conditions examined in Steps 22, 23, and 24 are satisfactory, ducting is not required; you may use free-flow air distribution, and the remainder of this step and all of Step 26 may be omitted. If any condition is unsatisfactory, ducting is necessary.</p> <ul style="list-style-type: none"> ● If more than one condition is unsatisfactory, any ducting planned must satisfy all conditions. ● On the drawings, sketch the route of the ducting and the location(s) of outlet(s) to overcome the problem(s). Keep in mind that: <ul style="list-style-type: none"> ● Only the supply needs to be ducted except in unusual circumstances. ● The duct should be as short as the requirement will allow. ● Changes in direction and size or cross-sectional shape of ducts should be minimized and curves should be as gentle as space will permit. 	

¹The 35% is another rule of thumb and is based upon considered judgement; it is believed close enough for your purposes in this handbook.

AIR DISTRIBUTION SYSTEM PLANNING INSTRUCTIONS

STEP NO.	STEP DESCRIPTION AND EXPLANATION	COMPLETED
	<ul style="list-style-type: none"> ● High velocity air (50 fps or higher) blowing directly on a person will be uncomfortable. The best approach for air at acceptable¹ velocities is directly from the front. The next best is from the side or from overhead. The least desirable, from the viewpoint of comfort, is from behind the person.¹ ● While comfort is not to be ignored, these systems are for use under field conditions where comfort must take second place to operational and logistical considerations. If in extreme weather conditions the temperature occasionally becomes a little warmer or a little cooler than desired, the occupants can dress accordingly. If there are times when the breeze from the ECU is blowing directly on an occupant and is either too strong or too cool, the occupant can change the louver setting to deflect the airflow. 	
26	<p>Once you have decided upon the location of the duct and the outlets, the size and cross-sectional shape of the duct should be determined. These may be controlled to some extent by the space available but you should try to keep them as close as you can to the dimensions of the supply discharge. The aspect ratio, that is, the ratio of the cross-sectional long dimension to the short should be as close to that of the supply discharge as practicable or else as close to 1:1 as practicable.² If the duct must be over walkways, there may be some constraint on the depth of the duct so that there will be sufficient head room. In this case, the vertical dimension will be the short one and the aspect ratio will be considerably more than 1:1. On the other hand, if the duct passes over cabinets, there may be room to make the aspect ratio approach 1:1. In any event, you should try to avoid an aspect ratio over 5:1. Determine the controlling dimension and, using the cross-sectional area of the supply discharge, determine the other dimension. You must accept that adequate may have to be good enough. Shelters are usually cramped for space with a number of valid needs competing for that which is available. Also, the small spaces sometimes dictate practices that would not be followed if more room were available. So, you do the best you can and take what you get.</p> <p>¹Reference 7, p 2-65. Acceptable velocities are between 18 psi and 50 psi; most favorable is around 25 psi.</p> <p>²See "Aspect Ratio" in Appendix I-1.</p>	

IV-4. Reductions and Expansions

As long as the volume of air being conducted remains the same (no takeoffs or outlets and no significant leaks), the cross-sectional dimensions should remain the same for the length of the duct. If space does not permit this, then a reduction in size or a change in shape becomes unavoidable. Any change should be made in a straight stretch of duct, if possible, and made with a thought to keeping the aspect ratio as low as possible. When a dimension must decrease or increase, the gentler the rate of change, the less the loss of efficiency.

• You should try to limit the angle of increase or decrease to not more than that shown in Figure IV-2.

MAXIMUM DESIRABLE CONTRACTION AND EXPANSION ANGLES

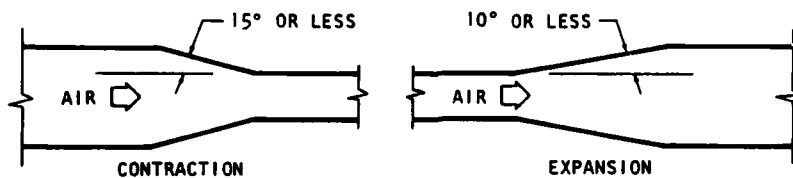


Figure IV-2. *MAXIMUM DESIRABLE CONTRACTION AND EXPANSION ANGLES*

• If you cannot stay within the limits shown above, the disadvantages of the wider angles can be lessened somewhat by the use of splitters to guide the flow generally along a less angular path (see Figure IV-3).

SPLITTERS IN EXPANSION AND CONTRACTION FITTINGS

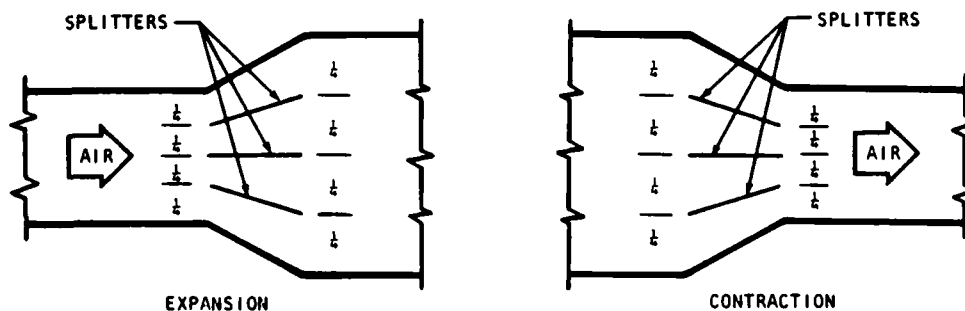
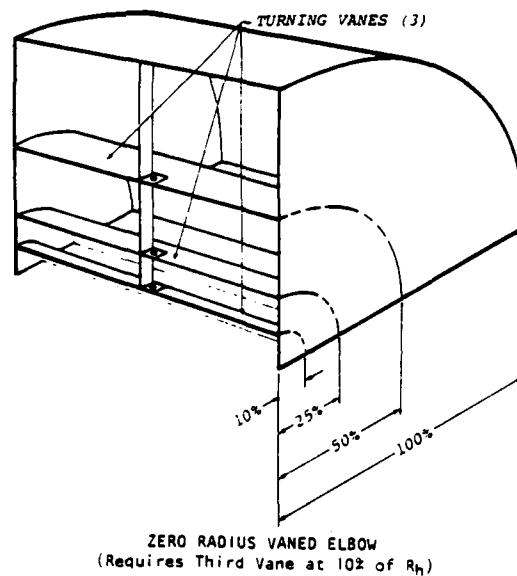
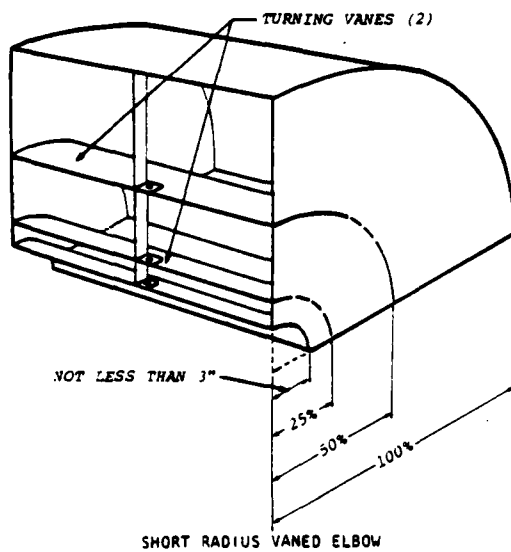
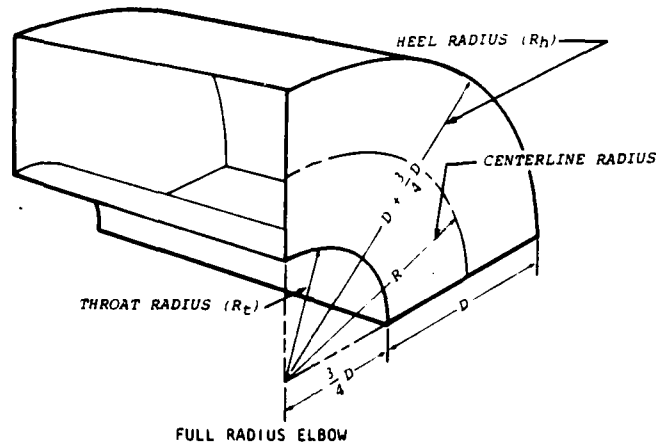


Figure IV-3. *SPLITTERS IN EXPANSION AND CONTRACTING FITTINGS*

IV-5. Bends

There are several types of bends, or elbows, for which you may have use. These are illustrated on the next page. Elbows for only rectangular ducting are shown since rectangular shapes are more adaptable to your needs.

CURVED ELBOWS



VANED SQUARE ELBOWS

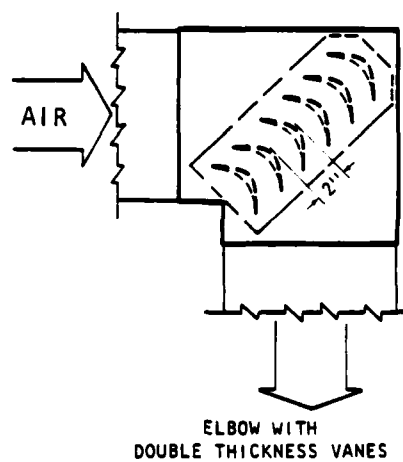
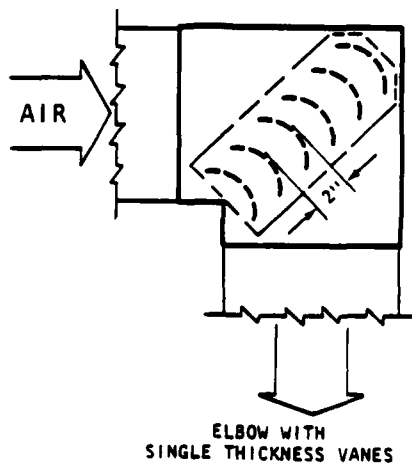


Figure IV-4. ELBOWS FOR RECTANGULAR DUCTING

- The full radius elbow, which by definition has an R/D ratio of 1.25, is considered optimum.

- Because of the limited space available in shelters, the chances are that you will be using mostly short radius (anything with R_t less than $3/4D$, including R_t equal to zero) or square elbows. In order of efficiency and reverse order of overall cost, elbows rank: full radius, short radius, and square.

- To improve their lower efficiency, short radius and square elbows normally require turning vanes. For curved elbows, the vanes should run the full length of the curvature and only two or three will be necessary for your applications.

- The square elbow requires numerous small vanes, the number depending upon the size of the elbows. There are two types of these: single thickness, which are the thickness of the sheet metal used to fabricate them, and double thickness configured to an aerodynamic shape as shown in Figure IV-3. The double thickness vanes are considerably more efficient and are preferable. A local heating and air conditioning contractor can probably prefabricate these for you.

- Figure IV-4 shows the location and spacing of vanes for both types of elbows.

IV-6. Takeoffs

Takeoffs are needed to channel some of the air from the main stream to a second destination. Two types should be considered for your applications: the diverging wye, which is the preferred takeoff, and the diverging tee for use where space prevents the use of a wye (see Figure IV-5). When you divert air from the main flow, you will need to know how much air you take off and how much remains in the main duct for other destinations. For the small systems dealt with here, an acceptably accurate way to estimate flow of air in the main and branch ducts is by direct proportion to the duct cross-sectional areas. For example, the flow of air in the main duct beyond the takeoff plus the flow in the branch must equal the flow approaching the takeoff. The lower part of Figure IV-5 provides a graphic means of making these estimations.

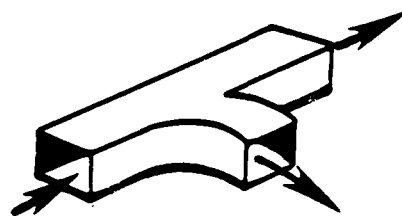
IV-7. Outlets

- Outlets are important elements of the distribution system even though they are at the end of the line. Their primary functions are to:

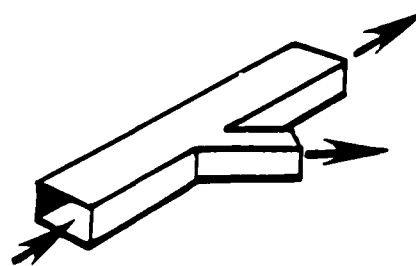
- Direct the air in desired directions.

- Regulate the spread of the conditioned air stream and the resultant entrainment of air already in the room.

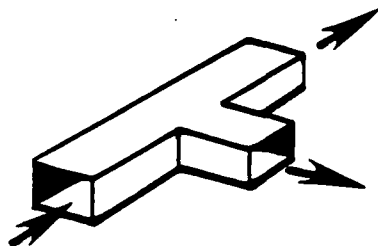
- Achieve entrainment at the desired rate; the higher the entrainment rate, the shorter the throw and the more quickly objectionable air velocities are reduced.



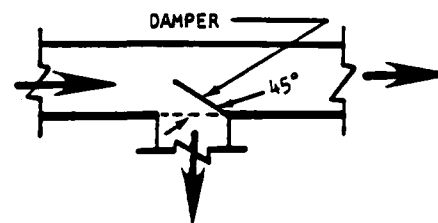
DIVERGING 90° CURVED WYE



DIVERGING 45° ANGULAR WYE



DIVERGING TEE



INTERIOR OF DIVERGING TEE
SHOWING NECESSARY DAMPER

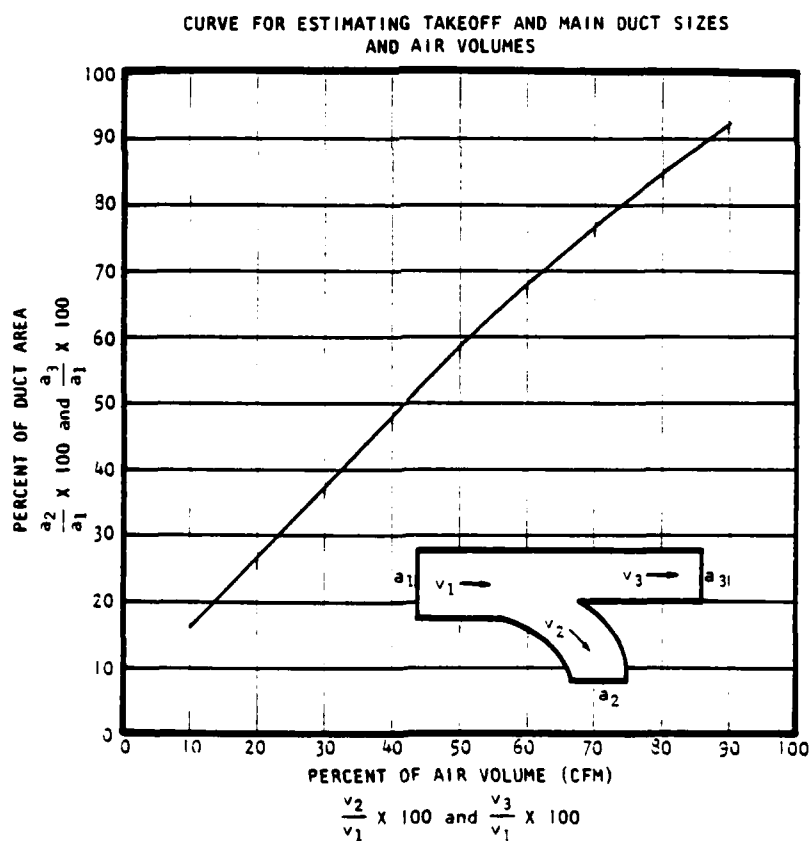


Figure IV-5. TAKEOFFS

- Wall Outlets.

- Grilles with individually adjustable louvers, such as those with the ECU, are the most desirable type of wall outlet. They can satisfy the above three points in most cases. Louvered grilles are available commercially in a variety of sizes.

- In some instances, however, the air can enter the compartment with such a velocity that it creates a high level of noise and draws complaints about uncomfortable breezes. In these cases, you may need a long, narrow outlet as illustrated in Figure IV-6 (as close to the width of the shelter as available space will allow and only 2 or 3 inches high). With this, the velocity will be reduced, cutting down the noise and the breeze.

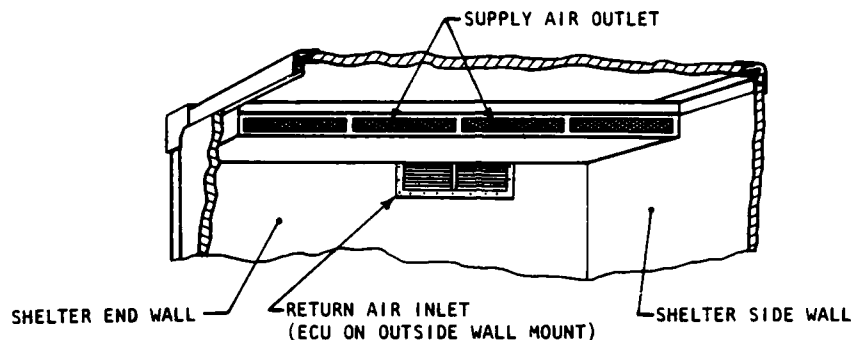


Figure IV-6. *OUTLET FOR REDUCING AIR VELOCITY AND NOISE*

- Ceiling Outlets. The two types of ceiling outlets that you should be concerned with are diffusers and perforated ceilings.

- As their name implies, diffusers disperse the air into the compartment. The approach of the air to the diffuser is a factor in its effectiveness. Two methods of achieving a satisfactory approach are illustrated in Figure IV-7.

- The perforated ceiling is a form of plenum and will probably find only rare usage for your purposes. If you think a plenum would be appropriate, consult an air distribution expert.

IV-8. Material

Weight and safety considerations lead to the recommendation that ducts be fabricated from 22-gage aluminum¹ and that all joints, seams, and connections be made airtight.

¹Reference 7, Table 14.

APPROACHES TO DIFFUSERS

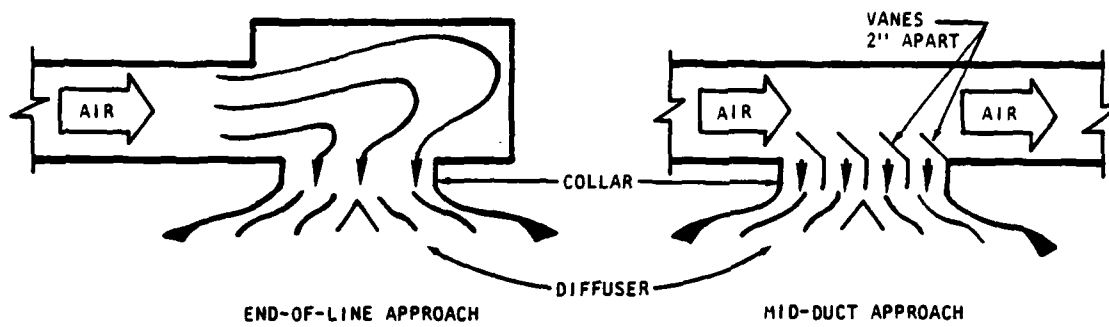


Figure IV-7. APPROACHES TO DIFFUSERS

SECTION V - PROTECTING AGAINST CHEMICAL, BIOLOGICAL, AND RADIOACTIVE FALLOUT CONTAMINATION

V-1. Introduction

Previous sections of this handbook were based on a peacetime situation, that is, no threat of an attack of any type. When the threat of attack is foreseeable, you must take into account some additional considerations. These relate to protecting yourself and your mission equipment while continuing to function effectively. This section looks at available means of protection against exposure to hazardous concentrations of CB agents and radioactive particulate fallout. (Thermal radiation, blast, and electromagnetic pulse are addressed in later sections.) Additionally, directions are included for adjusting the size of the ECU to handle the increased cooling load resulting from the use of CB collective protection equipment.

V-2. Threat

The threat of CB attack is most serious to personnel.¹ Therefore, for our purposes here, the threat can be narrowed to the potential entry into the shelter of CB agents and radioactive particles. The means of delivery is immaterial. The threat to equipment by CB agents is not serious.

- Contamination of the outside-mounted ECU does not cause significant problems. Even if contaminated, the function of the ECU will not be affected and it can operate for long periods without requiring maintenance.

- Chemical agents are mildly acidic but should do little or no short-term damage to military equipment. Decontamination agents are another matter, however. They are highly corrosive and should be used with great care; there is further discussion of this problem in paragraph V-11.

- CB agents and radioactive fallout, themselves, have no major destructive effect on materiel and facilities. Possible damage from other types of attack, preceding or simultaneous with the release of CB agents, are considered in Sections VI and VII.

V-3. Protection of Personnel

You can protect personnel in one of two general ways.

- Individual Protection. This is essentially a mask and special clothing. It is primarily for the individual who must work in an outdoor toxic environment. It is cumbersome, relatively uncomfortable, and inhibits the manual dexterity and mental concentration important for operating the complex equipment likely to be in most shelters. While it does not protect sensitive equipment, it could enable personnel within a shelter to survive and possibly work if collective protection should be disrupted. But while

¹Reference 8, Appendix II-2, contains a useful summary of chemical agent characteristics and effects.

individual protection has an emergency back-up place in your planning, it is not within the scope of this handbook so it will be dropped at this point. If you have need for information on individual protection equipment, Reference 8 of Appendix I-2 is a good source.

- **Collective Protection.** You can provide protection for one or more individuals by use of a contamination-free enclosure, such as a mobile shelter, or by ventilated facepieces. By pumping clean, filtered air into the shelter or facepieces, sufficient positive pressure is maintained to prevent infiltration of contaminants. Within an adequately sealed shelter, the shirt-sleeve environment important for mission effectiveness can thus be achieved. The collective protection system most suited to your needs, the MCPE, is discussed in the next paragraph. Other types and developmental systems are addressed in paragraph V-7.

V-4. Modular Collective Protection Equipment (MCPE)

- The MCPE provides sufficient, clean, filtered air to maintain a small positive pressure of 1.2 to 1.7 inches of water inside the shelter or enclosure to prevent penetration of contaminants from the outside.

- The system includes a gas particulate filter unit (GPFU), a protective entrance (PE), a static frequency converter (if 400 cycle power is not otherwise available), a power distribution unit, a compartment control module, and necessary flexible ducting and electrical cables (see Figure V-1). These are discussed below in the context of the interfaces between the GPFU, ECU, PE, and shelter.

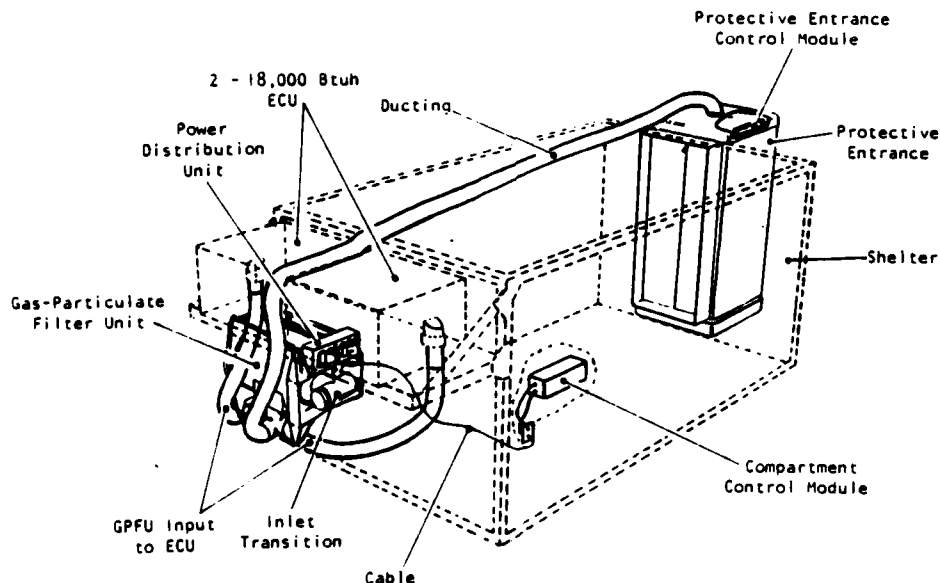


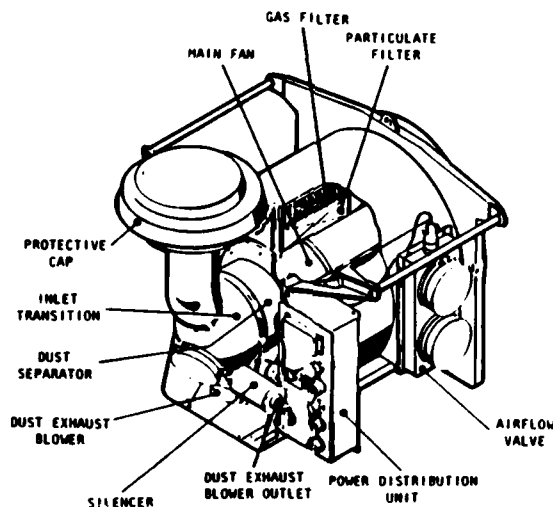
Figure V-1. MCPE APPLICATION TO PATRIOT SYSTEM ¹

¹Illustration from Reference 22, Appendix I-2. Note that the GPFU input to the ECU is through the fresh air intake which is on the side of the PATRIOT ECU. This is unusual and differs from Figure I-1-1 in Appendix I, which is the more common arrangement.

V-5. Interfaces

- MCPE-Shelter. You should consider the following:

●● GPFU. The filter unit is the heaviest element of the MCPE. Three sizes (capacities) of GPFU are available: 200 cfm, 400 cfm, and 600 cfm. (See Figure V-2.) Paragraph V-9 explains how to select the size suited to your need.



Unit	Dimensions in Inches			Weight (lb)	Power Consumption (KW)
	Height	Width	Length		
M56, 200 cfm	32.9	35.5	34.6	212.5	1.1
XM59, 400 cfm	32.9	35.5	44.8	271.2	1.6
XM62, 600 cfm	32.9	35.5	55.0	336.5	2.6

Figure V-2. GAS PARTICULATE FILTER UNIT ¹

- In most cases, the GPFU should be mounted on the ground using the stand available for this purpose (see Reference 22). In cases where wall mounting is required, you must be careful not to overload the shelter wall. ECU Wall Mount Number 2 (see Figure III-5, Section III) with some adaptation can accommodate the GPFU and one 18,000 Btuh ECU within the limits

¹Illustration from Reference 22.

of the wall capability. If an individual wall mounting option is required, the Physical Protection Division, U.S. Army Chemical Systems Laboratory¹ has a design which you should examine before expending effort on designing your own.

- Air from the GPFU is carried to the shelter (or to the ECU when one is used) through flexible ducting. This is very vulnerable to blast and fragments but there is not a good alternative at present. An aluminum duct, for example, might be almost as vulnerable because of its exposed location connecting the two units. Integration of the GPFU and ECU into a single package might help but efforts to date toward the end have not shown great promise (see paragraph V-6).

- To deliver the required volume of air, the GPFU blower requires 400 Hz power. Because power of this type is often not readily available, the MCPE includes a frequency converter for converting 50-60 Hz, 208 Vac, 3 phase power to the required 400 Hz, 208 Vac, 3 phase power. It will not work with single phase input power. The converter weighs 62 pounds and is 19.8 inches long, 8.5 inches wide and 8 inches high. It should be mounted vertically, to facilitate cooling, and may be mounted on the GPFU stand or mount, or directly on the shelter wall or floor. Since the converter uses solid-state devices, when EMP is a threat you should consider mounting it inside the shelter or, if outside, providing adequate shielding.

- The GPFU may prove useful in non-NBC situations where an effective capability to remove dust and supply a quantity of clean, fresh air is required. Conversely, in situations where dust will not be a problem, the GPFU may be used without the dust separator.

●● Compartment Control Module. This automatically regulates the compartment air pressure relative to ambient and must be mounted on the inside of the shelter. It is connected to the power distribution on the GPFU by an electrical cable which will require an entry provision in the shelter wall. (Note that all MCPE cables are unique to the system. You may obtain information on cables and connections from the Chemical Systems Laboratory.) When pressure falls below a safe level, a horn in the module sounds to warn personnel to don protective masks and equipment. At the same time, an indicator on the control module labeled "MASK" lights.

●● Protective Entrance.

- The PE is a pressurized transitional compartment. In it, personnel coming in from a contaminated atmosphere can be subjected to a recommended 5-minute air wash and can perform personal decontaminating operations before entering the shelter itself. Space inside the PE limits occupancy to one person at a time.

¹Telephone Number: AV 584-4222, Commercial (301) 671-4222.

Mailing Address: Commander/Director
U.S. Army Armament Research and Development Command
Chemical Systems Laboratory
ATTN: DRDAR-CLW-E
Aberdeen Proving Ground, MD 21010

- Positive air pressure within the PE assures an outward leakage to prevent entry of contamination. The PE pressure is slightly lower than that in the shelter, but the difference is low enough to minimize loss of shelter pressure when people enter or leave. The required pressure level is maintained in the PE by means of a protective entrance control module (PECM) which automatically adjusts air flow from the GPFU. The PECM is located in the air duct between the GPFU and PE.

- The PE is collapsible for transport. In use, it is 85 inches high, 44.1 inches wide, and 50.1 inches deep. Collapsed into its carrying package, it is only 12.5 inches high. It weighs 145 pounds and can be carried and erected by 3 men in 30 minutes.

- The standard PE is the M12 model. The M10 is almost the same, but has a longer skirt for the interface between the PE and the shelter. Although all PE's are unhardened and very vulnerable to fragments and blast waves, the XM14 model has a PECM which has been modified to meet nuclear hardness requirements, primarily from EMP. Since it is accepted that the PE will be lost to blast and fragments, you should plan to have replacements available. Because of this, as an alternative, you may want to consider establishing a protective vestibule within the larger shelters or perhaps a small, connected hardened shelter as a protective entrance to be used with smaller shelters. Their functions would be the same as the current collapsible PE. If there seem to be advantages in a more rigid and durable PE such as these, you should contact the Chemical Systems Laboratory¹ for advice and assistance.

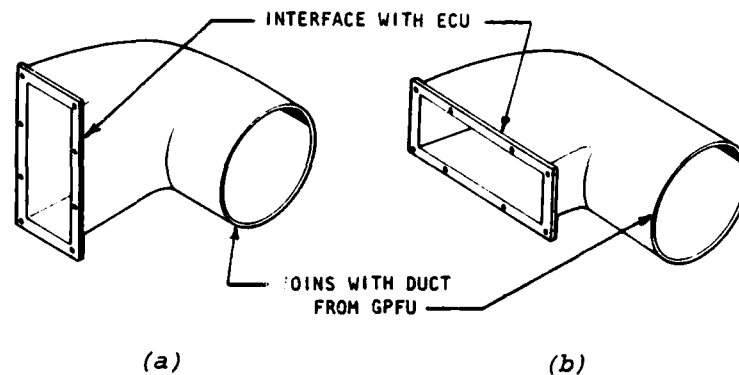
- Standard kits are available for interfacing with the S250 and S280 shelters. The modular design of the PE and its interfacing is intended to provide ready adaptability, nevertheless, you should examine the application to other shelters on a case-by-case basis to determine whether modifications are required. For truck-mounted shelters, the truck tailgate may have to be modified to handle the PE, and any shelter supported above the ground will require a platform to support the PE at the same level.

- When standard hardware is used, the air from the GPFU to the PE is carried by a flexible duct passing atop the roof of the shelter. This is very vulnerable to blast and fragments and spare ducting should be carried. But a better, more protected arrangement which you should consider is conveying the air from the GPFU to the PE through permanent ducting inside the shelter.

● MCPE - ECU.

●● In one application, the MCPE-ECU interface is provided by a flexible duct which conveys air from the GPFU to the ECU make-up air (fresh air) channel (note Figure V-3). This is only a portion of the GPFU output. In some applications, the remainder of the air goes all to the PE. In others, it goes partly to the PE and partly directly into the shelter. In yet another arrangement, the air is pumped into the shelter, which acts as a plenum with the air from the shelter to the PE, as in the other cases being automatically regulated by a PECM. In this arrangement, the ECU gets all its make-up air from the shelter. Supplying the PE with conditioned air from the shelter greatly increases the load on the ECU; therefore, this application is not recommended.

¹Ibid.



Transition (a) is more efficient than transition (b) and is to be preferred.

Figure V-3. TYPICAL TRANSITIONS FROM FLEXIBLE DUCT TO ECU MAKE-UP AIR INTAKE

●● In the Army AN/TSQ-73 application, where the GPFU provides fresh air to the ECU, there is a valve between the GPFU and the ECU which allows the air to by-pass the GPFU and go directly to the ECU when the GPFU is not working. When the filter unit is operating, the valve is held closed by air duct pressure to prevent contaminated air from entering. In all of the above cases, the ECU make-up air inlet must be closed when the GPFU is working in a CB environment or air leakage will prevent adequate pressurization.

● Summary of Concerns Regarding the MCPE.

●● Although the basic MCPE System has passed several nuclear hardening, EMI, and EMP tests, the unhardened shelter, the flexible ducting, and the PE are very vulnerable to blast and fragments. As a matter of fact, it is contemplated that the ducting and the PE will require replacement following a conventional or nuclear attack; for this reason, spares should be carried.

●● Exterior ducting is also subject to heat transfer from ambient conditions to filtered air. Because of this and the vulnerability of exterior ducting to blast and fragments, you should give consideration to interior shelter ducting to carry the air from the GPFU to the PE. For design guidance on efficient ducting, refer to Section IV.

●● You must seal the ECU-GPFU interface against entry of contaminants.

●● You must reassess your ECU selection. Guidance for this is provided in paragraph V-10.

- The additional heat load caused by the GPFU may exceed the cooling capacity of the ECU which was initially selected in Section II.

- Filtered air from the GPFU comes out 10°F to 15°F warmer than it goes in; this adds to the cooling load of the ECU and may require a larger unit.

●● You must seal the shelter well enough to permit the GPFU and ECU to maintain the necessary positive pressure without undue loss of air. Good sealing is necessary also to prevent a momentary reverse flow of air due to greater outside pressure, such as can be created by a blast wave or a passing truck. These problems and their regulation are discussed in Reference 22.

●● Sealing material used to reduce air leakage and protect against CB agent infiltration must be impermeable to air; resistant to CB agents, environmental extremes, and decontamination fluids; be easy to install; and be compatible with requirements for protection against EMP (see Section VI).

● More detailed information on the MCPE may be found in References 8, 13, and 22, Appendix I-2.

V-6. Integration of GPFU and ECU

In current applications, the MCPE and the ECU are not integrated into a single unit; they are not compatible to that extent.

● Although there may be components of similar purpose (e.g., blowers) in each, the components cannot perform each other's functions in their present configurations. Further, there are so many components dedicated to each unit's specific function that little could be eliminated through integration of the two units into a single package.

● The few attempts at a single, integrated system that have been noted are bulky and cumbersome to the extent that they required their own dedicated trailers for transport. Also, it is not clear how successful they are since no performance or test data have been seen, if, in fact, any have been collected.

● The separate units offer you certain advantages:

●● There is more flexibility in mounting arrangements.

●● The ECU can function alone when CB attacks are not imminent, thus saving power.

●● The demand for 400 Hz power can be held to a minimum (the GPFU requires it but the ECU can be in 50/60 cycle configurations).

●● In the event of a breakdown, one can be replaced without having to replace the other as well.

● If you find that an integrated GPFU-ECU system is an operational requirement, it is suggested that you contact the Physical Protection Division of the U.S. Army Chemical Systems Laboratory.¹ They should be able to advise you of the status of any integration efforts.

V-7. Other Collective Protection Equipment.

● Ventilated Facepiece Equipment. This is primarily to provide protection for crewmembers of a vehicle. It consists of a central GPFU connected to a facemask at each crew station. The system maintains a slight positive pressure and can provide adequate air (up to 20 cfm) for five crew stations. Since air is provided only at each crew station, it limits the mobility of the users.

●● A variation now in development provides for a compact, self-contained individual GPFU which can be carried by the user while it is in operation. By permitting the user to connect to either the central system or the individual GPFU, the mobility restraint of the multiple station is largely overcome.

●● In cases where use of ventilated facepiece equipment would be necessary, one would also have to wear protective clothing to prevent entry of CB agents into the body system through the skin. This leads to the same problems of encumbered movement that individual protection has.

●● If you want more information on this item, it may be found in Reference 8.

● Hybrid Collective Protection Equipment (HCPE), XM23, XM24, and XM25. Three sizes of the HCPE are currently in development: 100 cfm, 200 cfm, and 300 cfm. The HCPE is a combination of the positive pressure compartment and the ventilated facepiece systems. It is designed primarily for situations where closed compartment operation is possible part of the time and open hatch operation is necessary for the remainder.

●● The HCPE offers the advantages of both systems. But when facepieces are required, protective clothing should also be worn.

●● The variety of system components available and becoming available offer the flexibility of modular adaption to fit your need.

●● You may refer to page 47, Reference 8, for more information.

V-8. Caution

None of the filters in the equipment discussed above or in the GPFU will protect against carbon monoxide or ammonia fumes.

¹Ibid

V-9. Selection of GPFU Capacity

The selection of GPFU size is based upon the air flow requirement. There are several components of this requirement.

• **Shelter Leakage.** This is incidental leakage as opposed to deliberate venting. It can be determined only by test since it is largely dependent on how well the shelter is sealed against leaks. It should be measured at the positive pressure under which you will want the system to function. Some leakage, either incidental or deliberate, is required if ventilation requirements are to be met.

• **Ventilation.** Personnel health and comfort require ventilation. Multiply the average number of people occupying the shelter at any one time by 20 cfm per occupant to determine the ventilation air requirement. If in Section II you used a smaller figure than 20 cfm per person, then that figure should be used. If incidental leakage is insufficient to provide for the required ventilation, a means of deliberate venting must be provided. (The GPFU and ECU, after a certain pressure is reached, can input only as much air as can be leaked or vented.) Adjustable dampers are available for this purpose; two are illustrated on pages 235 and 237 of Reference 24. Also, most shelter manufacturers have workable dampers for this purpose.

• **Protective Entrance.** The PE must exhaust contaminated air after air-washing people who are entering the shelter. It therefore has a deliberate leakage of 125 to 150 cfm, depending upon the positive pressure to be maintained. This pressure, and the air flow to sustain it, incidentally, are automatically controlled by a pressure regulation network which is part of the PE system.

• **ECU Make-up Air.** This requirement is not a factor in determining the GPFU capacity. When the shelter and MCPE are used in a CB environment, one of two situations exists relative to the ECU make-up air (fresh air) intake (see Figure I-1-1). In one case, part of the GPFU output is passed through the ECU for conditioning before entering the shelter; in this case, it is ducted directly to the ECU make-up air intake. In the other case, the GPFU air enters the shelter first and then is taken into the ECU, through the return air inlet, for conditioning. In this latter case, the ECU fresh air inlet damper must be closed to prevent loss of shelter air pressure. In either case, the make-up air is not an air flow requirement for the GPFU.

• **Air Flow Requirement Determination.** This can best be explained with the following illustrative example.

Shelter Leakage. For the purpose of the example, it is assumed that the shelter test showed a leakage of:

140 cfm

Ventilation. Two people are assumed to be in the shelter. At 20 cfm/person, the requirement is:

40 cfm

Protective Entrance. The PE is assumed to be at 1.5 cfm and requires:

125 cfm

Analysis.

●● The shelter leakage (140 cfm) exceeds the ventilation requirement (40 cfm), so ventilation is satisfied through incidental leakage; deliberate venting will not be required.

●● The total of the leakage to be made up plus the PE requirement is 265 cfm (140 cfm plus 125 cfm). This is too large for the 200 cfm filter size and the 400 cfm unit will be required.

●● If the leakage can be reduced by better sealing, to where the loss is only 75 cfm, then the total would be 200 cfm and the smallest GPFU filter size can be used. This is an advantage if it will prevent having to go to a larger ECU. Besides the drawback of an oversized ECU mentioned in Section II, paragraph II-9, a larger ECU would use more power as also would the larger GPFU.

● If a GPFU is added to the air system of the shelter, regardless of size, the ECU size determination must be re-evaluated as explained in the next paragraph.

V-10. Reassessment of ECU Size Based Upon Use of the GPFU

As mentioned in paragraph II-5, ambient (outside) air temperature is raised by 10°F to 15°F when it passes through the GPFU. This makes it necessary that you recompute Step 4, Worksheet, Part I, and Step 7, Worksheet, Part II, to determine the increased load on the ECU. The values in spaces 4a and 7a of the worksheets are taken normally from Columns G and H of Figure II-1. When the GPFU is to be used, these values should be taken instead from Columns I and J of Figure V-4 (next page). For worksheets which have already been completed without consideration of the GPFU, the Figure V-4 values should replace those in spaces 4a and 7a and the heat gain or loss for ventilation recomputed. The total cooling requirements or net heating requirement should then be re-determined.

V-11. Decontamination

Once NBC contaminants have been deposited on equipment, sooner or later they must be removed or neutralized. As mentioned in paragraph V-1, decontaminating agents are highly corrosive and can damage rubber, certain plastics, and metal. For this reason, you should avoid the use of the standard decontaminating agents on the ECU and shelter seals if less stringent means are available. If they must be used, these agents should be applied as prescribed but should be washed off, as soon as instructions for use permit, with soapy water and a clean water rinse which, themselves, are effective in removing contaminants. Also, if you use decontaminating agents, you should avoid applying them to areas not touched during maintenance, closed compartments not contaminated, and areas where it will be difficult to rinse after decontamination. The following subparagraphs discuss the standard agents for decontaminating equipment and alternatives which might be available to you.

CLINATIC CATEGORIES	I	J
	SUMMER VENTILATION HEAT GAIN (BTUH/CFM)	WINTER VENTILATION HEAT GAIN (BTUH/CFM)
A1 HOT DRY	62	66
A2 MOD HOT DRY	50	66
B1 WET WARM	NA	66
B2 WET HOT	116	66
B3 HUMID HOT	140	66
C0 MILD COLD	55	66
C1 MOD COLD	55	94
C2 COLD	55	120
C3 SEVERE COLD	55	130
C4 EXTREME COLD	55	141

Figure V-4. VENTILATION FACTORS WHEN GPFU IS USED

● Decontaminating Agent, STB (Supertropical Bleach). STB is a mixture of chlorinated lime and calcium oxide that can be used against all liquid chemical agents and some biological agents. It is available in powder form in 8-gallon drums. It is applied as a powder or as a slurry.

●● It is recommended that you not use STB on equipment covered in this handbook. It is highly corrosive to most metals and injurious to most fabrics. It is toxic and flammable.

●● Under development is the XM14, Truck-Mounted, Power-Driven Decontaminating Apparatus which includes a capability to dispense STB as well as capabilities for steam cleaning and vehicle washing. This would permit you to decontaminate with STB and follow with a good cleaning; thus, overcoming some of the objectionable features of STB.

●● For further information, refer to pages 103 and 131 of Reference 8.

● Decontaminating Agent, DS2. DS2 is 70 percent active agent (diethylenetriamine), 28 percent solvent (ethylene glycol monomethyl ether), and 2 percent active agent booster (sodium hydroxide). It is available in liquid form in either 1-1/3-quart cans or 5-gallon drums.

●● DS2 is effective against all known toxic chemical agents if allowed to remain in contact to a maximum of 30 minutes. It is effective against the nerve agent GB and mustard gas HD within 5 minutes.

●● As with STB, you should avoid use of DS2 on the ECU and its ancillary equipment if you can. But, if a choice between STB and DS 2 must be made, DS2 would be preferable in most cases.

- DS 2 has a low flashpoint and can be a fire hazard if used on heated equipment.

- It is irritating to the eyes and skin and the vapor is harmful if inhaled.

- DS2 removes and softens new paint, except polyurethane paint, and can discolor old paint and polyurethane. It will also soften leather and rubber products.

●● You may find further information on page 111 of Reference 8.

● Alternatives to STB and DS2. The following alternatives are primarily means of removing the contamination from the equipment rather than neutralizing it. An exception is the heat method which can neutralize most chemical and biological agents. You must remember that if an agent is just removed, as in washing, it still remains a potential danger even in the waste water.

●● Heat will vaporize most chemical agents and permit them to be dispersed by evaporation into the air in non-injurious concentrations. The temperature necessary for heat alone to do the job is a minimum of 180°F. How this might be achieved is a question which greatly limits its application at present. However, there are two items of equipment under development which you might find applicable.

- The XM16, Truck-Mounted, Jet Exhaust Decontaminating Apparatus is basically a jet engine. This item is operated in pairs. A contaminated vehicle is driven slowly between the two with the hot jet exhausts being directed at it from both sides, raising surface temperatures to between 212°F and 234°F. For more information, see page 137 of Reference 8.

- The XM15, interior surface decontaminating system is being developed for use inside vehicles and shelters. The system as presently configured is too large for its intended use and effort is underway to reduce the size to about 1 cubic foot. It is expected that it will generate temperatures up to 194°F. More information may be found on page 139 of Reference 8.

●● Washing with a strong alkaline soap (e.g., GI soap) and hot water will likely remove CB decontamination as well as radioactive particles and achieve a small degree of decontamination. This is fairly easy for small, outside surfaces but it may be difficult to reach some interior sections of the ECU.

●● Rinsing with plain water may not neutralize the agents but it will probably remove enough to reduce their chances of causing injury. An item being readied for adoption by the U.S. Army is the XM17, Lightweight, Hot Water Dispensing, Decontaminating System. This, called the NBC Sanator, is standard equipment for the Norwegian and Swedish forces. It provides a hot water rinse for shelters, vehicles, and equipment. It draws water from any source, heats it, and delivers it at 100 psi at controlled temperatures up to 248°F. Additional information is on page 135 of Reference 8.

●● Steam cleaning is a very effective means of removing and perhaps neutralizing contaminants without damage to the ECU or protective equipment. A mobile steam generator would be a very handy piece of equipment to have for this. As mentioned above, the developmental XM14 decontaminating apparatus includes a steam generator and, if available, would provide a means of steam cleaning the ECU.

SECTION VI - PROTECTION AGAINST ELECTROMAGNETIC PULSE (EMP)

VI-1. Introduction

EMP is an intense burst of electromagnetic energy resulting from a nuclear explosion. The energy released can disrupt communications and burn out electronics, especially solid state components which are extremely susceptible to EMP, hundreds of miles from the blast. Any conductor, a telephone line, a powerline, or a grounding line, for example, can pick up the pulse and carry it for miles into equipment which might otherwise be shielded. Because of EMP, control of the environment within the shelter raises three problems with which you must deal.

- One is the restoration of the electrical continuity of the shelter enclosure which was interrupted by the holes cut into the walls. But these holes are no different than the holes required by other types of equipment which you already know how to handle.

- The second is the vulnerability of the ECU and the MCPE.

- The third is the ECU-shelter interface.

This section offers you guidance on the second and third of these problems.

VI-2. Anticipated Threat

It seems generally accepted that the assumed threat, which is classified, requires an attenuation of 60 dB over the range of 0.15 MHz to 10 GHz and 80 dB over the range of 0.20 MHz to 1 MHz.

VI-3. ECU and MCPE Vulnerabilities

- ECU. The ECU has a number of components which are particularly vulnerable to EMP.¹

- The two chief causes of concern are the solid-state rectifier and the solid-state time delay relay. EMP can cause damage and even total failure in both of these.

- Other elements which may also be weak links in the chain are the capacitors, the filters for DC current, and the starters. While these are not solid-state, the very high currents and voltages induced by the EMP could cause component upset even if they do not cause permanent damage.

- Additionally, EMP-induced currents and voltages may cause circuit breakers to open or fuses to blow.

¹The only exception at present is the 18,000 Btuh Split-Pack ECU developed for the PATRIOT System. This is believed to be protected to an adequate EMP attenuation level although this is yet to be confirmed by testing.

● MCPE. The MCPE has passed basic EMP testing and the version being used for the PATRIOT system has been modified to provide even greater resistance to EMP. The modifications include part of what will also have to be done with the ECU: the elimination of all solid-state circuitry and the provision of shielding and filtering in the electrical cables. The MCPE is not considered a problem.

VI-4. Remedy for ECU Weaknesses

There are two courses which you can follow in overcoming the ECU's vulnerabilities.

● The best course is to request the DOD proponent agency¹ to furnish you with ECU's which have the requisite protection. The advantages of this:

●● It would provide a basis in demand for the establishment of a program to develop protected ECU's over the range of unit sizes which you need.

●● It would eventually place into the DOD procurement system EMP-protected ECU's and make future acquisition of these units simpler and quicker.

● The other alternative is to retrofit existing ECU's. This may possibly produce quicker short-term results and might warrant your consideration in conjunction with the above course. Retrofit is sufficiently complicated so that you should have it done at the factory and have it done against performance specifications, to include required EMP attenuation (see paragraph VI-2, above), rather than an enumeration of work to be done.² The work should include at least the following and might include other items if the retrofit facility believes them necessary to meet the required performance:

●● Replacement of solid-state components with vacuum tubes or mechanical components or the placement of solid-state circuitry in EMP-shielded and sealed enclosures.

¹Commanding General

U.S. Army Troop Support and Aviation Materiel Readiness Command
Attention: DRSTS-WX
4300 Goodfellow Boulevard
St. Louis, MO 63120

(Procedures for placing a development requirement are contained in DARCOM Regulation 700-5).

²The requirement for all EMP protective materials to withstand CB agents, thermal radiation, temperature extremes, corrosive effects of the atmosphere, galvanic erosion, and air pressures (from within the shelter as well as external nuclear overpressure) also should be spelled out in some detail in the performance specification.

●● The shielding of all other sensitive components (e.g., capacitors, circuit breakers) perhaps by placing them also in sealed enclosures. You might consider the possibility of remote mounting the circuit breakers inside the shelter. This would provide shielding as well as safe access for resetting.

●● Conductive sealant at all seams.

●● Conductive gasketing on all doors and access panel enclosures.

●● Filtering at control and power cable entries.

●● Conductive honeycomb barriers on all uncovered openings.

●● Shielded cables.

●● All bolts and rivets solidly seated with clean metal-to-metal contact or installed after dipping in conductive sealant and sealed against the environment.

VI-5. ECU-Shelter Interface

The interface should restore the conductivity and shielding of the unbroken aluminum skin of the shelter. It should also seal well enough to maintain the positive air pressure necessary for CB protection within the compartment. Achievement of these two objectives is basically a matter of gasketing.

● There are a number of types of EMI/EMP gasketing on the market which can provide the shielding effectiveness (EMP attenuation, air pressure seal, and resistance to chemicals and temperature extremes) you require. Examples of some which may be suited to your need are:

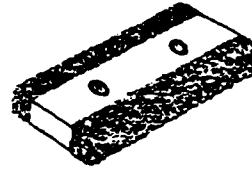
●● A metal mesh of knitted, springy, resilient, interlocking wire loops (see Figure VI-1(a), (b), and (c)). Metal mesh cannot, by itself, provide a pressure or environmental seal; it must be used in conjunction with an elastomer as illustrated in Figure VI-1(a). A type of gasket not shown is an elastomer core surrounded by wire mesh. This can provide an environmental as well as an EMP seal but is of questionable reliability as a pressure seal.

●● A solid or sponge silicone elastomer with embedded, conductive shielding wires oriented perpendicular to the mating surfaces (Figure VI-1(d)).

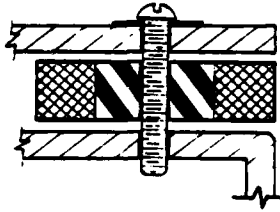
●● A solid silicone elastomer with continuous metal conductive paths throughout the gasket with many surface contact points (Figure VI-1(e)).

● The oriented wires and the contact points of the conductive paths protrude from the surface of the gasket and, under compression, cut through any buildup of nonconductive oxidation to establish good electrical contact with the mating surfaces. The solid elastomer will probably provide you with a better pressure seal than will the sponge but achieving and

KNITTED WIRE MESH

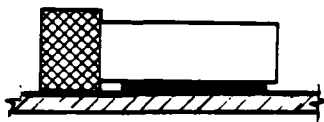


(a)



Two formed or compressed mesh strips in parallel with sponge elastomer strip. Affixed with bolt through bolthole. Can be affixed also with adhesive. Thicknesses available: 0.062 to 0.375 inch.

(b)



Formed mesh strip in parallel with mesh attaching strip. Affixed with conductive or nonconductive adhesive. May be obtained with boltholes in attaching strip. Thicknesses available: 0.04 to 0.375 inch.

(c)



Round mesh strip with extruded metal attaching fin. Affixed with conductive or nonconductive adhesive. May be obtained with boltholes in fin. Thicknesses available: 0.062 to 0.500 inch.

METAL CONDUCTORS EMBEDDED IN ELASTOMER

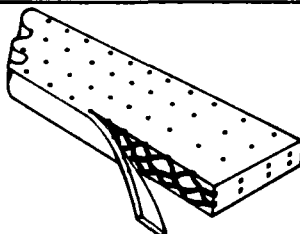


(d)



Shielding wires in matrix of solid or sponge silicone elastomer. Wires oriented perpendicular to mating surfaces. Affixed with conducting elastomer. Provides composite EMP and pressure seal. Thicknesses available: 0.030 to 0.500 inch.

(e)



Multiple layers of solid copper conductive paths in solid or sponge elastomer. Contact points coated with special tin alloy. Thicknesses available: 0.125 to 0.625 inch.

Figure VI-1. SOME EXAMPLES OF EMP GASKET MATERIALS

maintaining adequate compression pressure will be more difficult than with the sponge elastomer. In designing a gasket, you should understand that a sponge elastomer compresses into a smaller space while the solid elastomer does not compress but rather deforms and flows while maintaining a constant volume. Space must be allowed in your joint design for this.

- The oriented wires and metal conductive paths should have galvanic compatibility with the mating surfaces to reduce galvanic erosion and corrosion. Since both the shelter and, in most cases, the ECU enclosures are aluminum, aluminum in the gasketing would be appropriate. You might find it desirable insurance to apply a chromate conversion coat to both mating surfaces to retard oxidation. Within 3 miles of the sea (saltwater) you should also apply a 0.003 inch (0.0766 mm) coating of silver-filled epoxy.

- The service life of the gasket is another factor you should keep in mind. The gasket material should be resistant to or protected from abrasion, moisture, chemicals, and thermal radiation. Also, close attention should be paid to manufacturers' specifications since some elastomers change under temperature extremes, becoming hard and brittle in extreme cold and soft and foamy in extreme heat. In either case, a loss of seal can result.

- Compression pressure (to compress the seal between the mating surfaces) is important in developing the full EMP shielding and pressure/environmental seal effectiveness of the gasket.

- The sponge or solid elastomer must be compressed or deformed sufficiently to fill all the unevenness between the two mating surfaces and to force the wire tips or contact points through any oxidation buildup. Depending upon the situation and the material, you will need to obtain a compression pressure of 20 to 100 psi.

- The concern in this respect is primarily with wall mountings, since the seal between the heavy ECU and the shelter might be broken if the mounting should flex during transport.

- Reference 14 offers a thorough discussion of EMI/EMP gasket design theory and a design procedure.

- The flexible ducting, or connecting boot, of the ground mounts is unshielded; therefore, an EMP gasket at the interface of the duct and the shelter would give you no benefit (CB sealing is still vital, however). In the case of ground mounts, EMP protection for the shelter interior must be provided by conductive honeycomb barriers in the air passages through the shelter wall. An illustration of a honeycomb barrier is at Figure VI-2(a).

- Pressure sealing is essential to the maintenance of the positive shelter pressure necessary for CB operations. When properly installed, both the solid and sponge silicone elastomer gaskets already mentioned are rated very highly in this respect: up to 30 psi. This should also withstand the overpressures generated by a nuclear blast at a level which the shelter, itself, would survive.

• A useful non-gasket type of shield for doors which are repeatedly opened and closed is the metallic spring finger strip, an example of which is illustrated in Figure VI-2(b). This type of shield provides no pressure or environmental seal and must be used with environmental and pressure seals such as elastomer gaskets. Careful and proper installation of the spring finger strips is necessary to reduce damage from normal use and traffic. A type of damage that often occurs is that in which a finger is snagged on a passing object, a person's clothing for example, and broken. This would likely negate the effectiveness of the shield. For best effect, installation should be so that the fingers scrape the contact surface during closing to assure that non-conductive oxides, which may have formed, are wiped off.

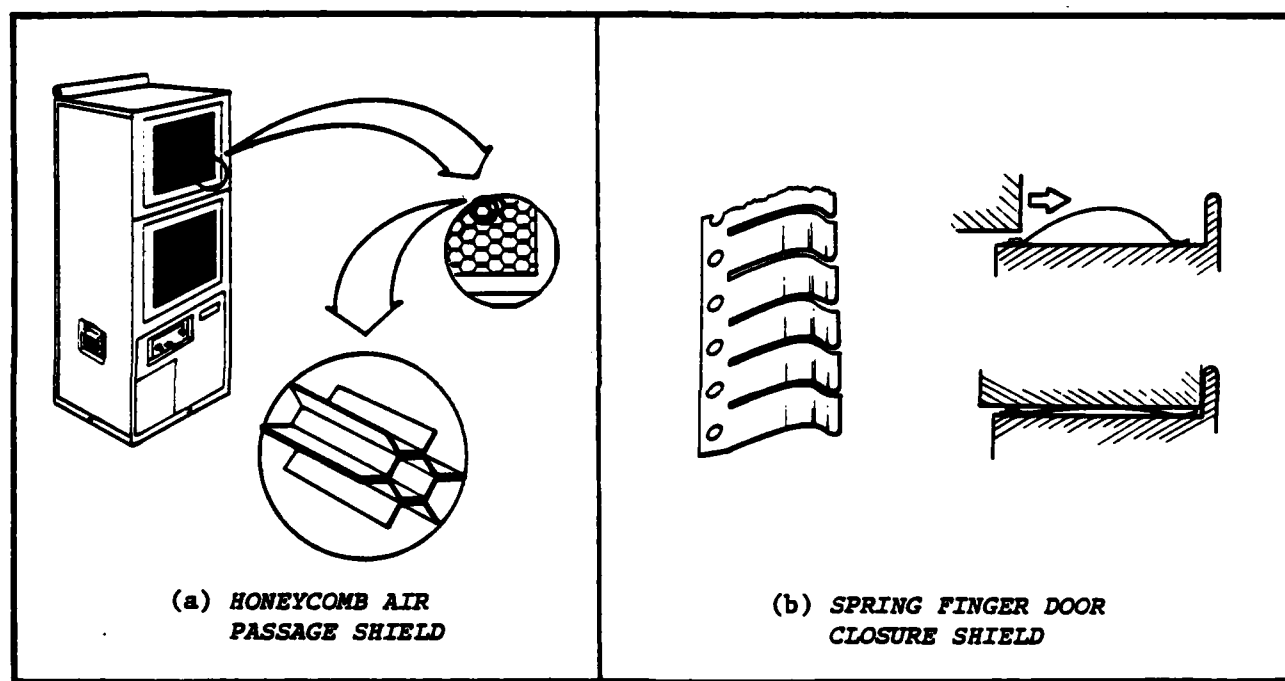


Figure VI-2. EXAMPLES OF EMP SHIELDING FOR AIR PASSAGES AND DOOR CLOSURES

• This handbook does not attempt to designate the specific shielding you should use. But the foregoing has highlighted considerations that must bear on your selection. It is strongly suggested that you consult with several of the leading manufacturers of EMP shielding materials for their recommendations on the best materials for your need and the most effective procedures for installation. When presented with specific requirements, a manufacturer may be able to propose combinations of sealing materials and methods tailored to your need and to guarantee the required results. Appendix VI-1 contains a list of randomly selected but representative firms which manufacture EMP shielding materials or which can provide engineering and design assistance for solving shielding problems.

SECTION VII - BLAST AND THERMAL PROTECTION

VI-1. Introduction

This section addresses actions that you might take to reduce the vulnerability of ECU's, MCPE's, and related equipment to nuclear blast and thermal radiation.

- For the purposes of this section, blast effects include those resulting from overpressure (the excess pressure over atmospheric pressure caused by the shock front) and the dynamic pressure resulting from the strong winds immediately behind the shock front. Thermal effects result from the short duration, intense heat generated by the blast. The thermal pulse arrives two to three seconds before the shock front.

- There are current efforts to perfect techniques for hardening mobile shelters (see References 16 and 17, Appendix I-2). If and when these techniques are perfected and can be applied to all shelters, the best protection for vulnerable equipment would be to mount it inside the shelter. While this may not be practical with the smaller shelters (S280 and below), it becomes more inviting with the larger shelters where there may be sufficient space to partition off a section for the ECU and GPFU. (Soundproof and insulated partitioning can reduce the noise and heat problems mentioned in Section III.) But with the present unhardened, indeed, soft, shelters, interior mounting offers little gain in protection against blast. There should, however, be one-time (see paragraph VII-2, below) protection from the thermal pulse for interior mounted equipment simply because it would be shaded from direct radiant exposure.

VII-2. Assumed Threat

- References 16 and 17 address nuclear hardened shelters in the context of the HATS (Hardened Tactical Shelter) program and for this purpose work with the following nuclear threat:

- Peak free-field overpressure of 7.3 psi with a pressure positive phase of 1.0 second.

- Thermal pulse with a fluence of 65 calories per square centimeter, deposited in 2 seconds.

- The HATS threat is well beyond what an unhardened shelter can be expected to survive.

- This level of overpressure with the accompanying dynamic pressures would cause crushing and displacement of the shelter and a tearing away of the CB protective entrance and any exposed flexible ducting.

- The temperatures associated with the HATS level of thermal pulse might well, in the worst case, reach 2000°F, or above in the shelter's directly exposed aluminum skin. This is approaching twice the melting temperature of aluminum. Even in cases in which the duration of the pulse should be too short to cause melting, there would in all likelihood be almost

a complete and permanent loss of strength in the skin. The aluminum members of the ECU wall mounting frame would fare better. They are thicker and heavier than the skin and therefore, those directly exposed to the thermal pulse would experience internal temperatures not much over 300°F. But even at this temperature, these members also could suffer a drastic, although temporary, loss of strength, possibly up to one-half. They should recover almost completely when returned to normal temperature, however. These thermal effects will probably be the same for the exposed elements of the ECU.

•• The thermal radiation temperatures can also cause burning or blistering of paint and ignition or charring of exposed parts of gaskets, flexible ducting, protective entrance material, and other materials sensitive to the short duration, intense heat. Exposed portions of materials which depend upon flexibility for their effectiveness could lose their effectiveness by becoming brittle or too soft.

Until the hardened shelters become available, the present unhardened versions are the ones you must be concerned with. It is estimated that the current unhardened S280 shelter, as an example, can withstand approximately 0.3 psi nuclear peak, free-field overpressure or 1.3 psi static equivalent overpressure loading. There appears little payoff from deliberately hardening ancillary components beyond this level. However, much equipment is already beyond that level and designing the ECU mounts for railroad humping has given them a degree of nuclear hardness as well. This and reasonable protective measures, if deemed necessary, are addressed in the following two paragraphs.

VII-3. Current Hardening Status

• ECU Mountings. The mountings for the ECU's (with the exception of the retractable mounting in its extended position) are all designed to withstand railroad hump loadings (see paragraph III-2). A side benefit of this is the capability to survive an estimated nuclear free-field peak overpressure of 4 psi with the following caveat: those members of the mounting frame which are directly exposed to the unattenuated thermal pulse may have a reduced strength at the time the shock front arrives. The ground mounts, too, have this built-in hardness but they must also be well anchored with guy lines at top and bottom to reduce shifting and to prevent the taller mounts for vertical ECU's from tipping.

• ECU. The military ECU, itself, is a fairly sturdy piece of equipment.

•• Blast.

- The 18,000 Btuh PATRIOT horizontal ECU, a unit designed for added durability, has demonstrated in blast tube tests the ability to stand up to approximately 7.3 psi overpressure and continue to function. (Other units have not been so tested and their durability is questionable.) But the PATRIOT ECU did suffer some deformation to its enclosure which, if seams were opened or panels sprung, could cause problems if it is subsequently subjected to EMP. Further, the overpressure load which pushed in the side of the enclosure could have compromised the air-tight seals necessary for CB

protection, internally, between the compressor and the evaporator and, externally, in the ECU-shelter interface. What actually happened to such seals, if in fact they were in place for the test, is unknown since no data on this were collected.

- The blast tube test resulted in failure of the enclosure panels of the standard 18,000 Btuh vertical unit. Since then, the panels have been reinforced against this type of failure but the ECU has not been re-tested. Nevertheless, these units manufactured subsequent to 1981 incorporate the additional hardening.

•• Fragments. The enclosure which houses the ECU is for protection from the elements, not from an attack. High velocity fragments from either a nuclear blast or a conventional attack can be expected to penetrate it and to cause internal damage to the ECU. Also, for the remote ground mountings, the flexible ducting in all likelihood would be damaged or destroyed.

•• Thermal Radiation. The exposed sections of the ECU's aluminum enclosure will probably suffer to some degree from any direct thermal radiation received. But the enclosure will provide adequate thermal shielding for the internal works. Any exposed gasketing or sealing would be subject to damage unless a high heat-resistant material is used. This applies also to any exposed flexible ducting.

• Modular Collective Protection Equipment. The basic MCPE (see Section V) has passed several nuclear hardening tests.¹ However, the flexible ducting and the protective entrance are soft, completely exposed elements. (It should be noted that most current concepts envision that the interface between the ECU and the GPFU be a flexible duct.) They would certainly be damaged beyond their ability to continue their function by any attack causing flying fragments. Also, the projected nuclear overpressure and dynamic pressure would tear them away. Either of these situations would be critical if the conventional or nuclear attack were accompanied or followed by a CB attack. Unless the duct and PE could be replaced prior to the CB attack, contamination within the shelter would be almost unavoidable. Anyone leaving the shelter to put up replacements would open the door to contamination and the MCPE could not provide the necessary positive pressure in the shelter with no ducts for delivering the air.

VII-4. Protective Steps

• ECU.

•• Wall-mounted ECU's. Other than using heat-resistant gasketing and sealants, there is not a whole lot more that you can do directly to the ECU; it cannot be changed substantially without a major redesign or retrofit. External to the ECU, armor plate (steel, aluminum, Kevlar) can be added to the top, bottom, and both sides. The rear (condenser intake and

¹Reference 22, Appendix I-2.

discharge end) must remain largely exposed, except for EMP shielding, to prevent inhibiting the air flow necessary for the ECU's proper functioning. The vulnerability of the rear can be reduced by the use of a baffle plate but great care should be taken to assure ample passage of air. The method of determining clearance described in Figure IV-1 should be useful in this respect. The armor will also provide adequate shielding against thermal radiation for those areas that it shields.

●● Ground Mounts. Remote ground mounts are particularly vulnerable because of the flexible ducting. In situations where there is risk, you can significantly reduce the risk by flush-mounting the ECU as illustrated in Figure III-6. Protection of the ECU, itself, can be accomplished in the same manner as discussed immediately above.

● MCPE.

●● Flexible Ducting. The first thing that you should do is to eliminate the flexible ducting. There are two ways you can do this.

- The first is to run the air duct for the PE through the shelter (see Section IV). You should give consideration to insulating this duct since the GPFU raises the temperature of the air it pumps through it by as much as 150°F above ambient. This added heat will increase the load on the ECU.

- The second way is to use the shelter interior as a plenum which conducts the air to the PE. The flow to the PE must be regulated by an automatic valve which can operate at the same time to maintain the necessary positive pressure in the shelter. When the PE is blown away during an attack, the valve must stop the flow of air; it must also accommodate to sudden, momentary high pressures outside the shelter which might reverse the leakage flow and force contaminants into the shelter. (A valve to regulate flow and pressure is essential to the method described immediately above, as well.) This second method can put a large burden on the ECU since it uses conditioned air for the PE air wash function.

VII-5. Protective Siting and Protective Construction

In the period before hardened shelters become available, it seems almost futile to harden ECU's and MCPE's. But hardening these ancillary items may give an edge to survival, albeit a very slight one. However, the shelter can also be given improved protection which will at the same time enhance the survival prospects of the ECU.

● Siting. Operational considerations permitting, you should look for places to put the shelter which are away from likely targets. Further, you should strive to take advantage of terrain features to place the shelter in defilade from likely directions of blast and thermal effects as well as from conventional attack. You might orient the shelter so that the smallest dimensions face the likely location of blast and that the most vulnerable apertures are on the away side of the shelter.

• Construction. You can use protective construction to substitute for protection afforded by the terrain or in conjunction with the terrain to enhance protection. Protective construction would be limited to protecting the shelter (bunkers could replace the shelter). It would probably take the form of revetments and berms (similar to those which protect aircraft in parking areas at forward airfields). Entrenching is another form of construction that offers possibilities.

• Without overhead protection, such as offered by hardened aircraft shelters, the electronics shelters remain rather vulnerable. But the siting and construction suggested above may shield against direct thermal radiation, intercept fragments, or deflect a shock wave just enough to permit survival which might otherwise not be possible. In other words, you should take advantage of every opportunity to give yourself an edge.

APPENDIX I-1. EXPLANATIONS AND ILLUSTRATIONS OF TERMS

Aspect ratio - In the cross-section of a duct, the ratio of the long side dimension to the short side dimension. The most efficient (least pressure loss) and least expensive duct (materials, fabrication, and installation) is round with a given aspect ratio of 1:1. The next most efficient and next least expensive is square, with an aspect ratio of 1:1. As the aspect ratio increases, the cost increases and the efficiency decreases. For the small systems dealt with here, these factors have relatively small impact as long as the aspect ratio stays below 5:1.

Btuh (British thermal units per hour) - The English system unit of heat transfer rate in which all heat loads and capacities discussed in this Handbook are expressed. 1 Btu = amount of heat required to raise 1 lb of water 1°F.

Cooling capacity - The measure of the ability of an ECU or air conditioner to remove heat from an enclosed space.

Cooling load - The rate at which heat must be removed from an enclosed space to maintain a given inside air temperature.

Environmental Control Unit (ECU) (See Figure I-1-1) - Any device which processes air (cooling, heating, ventilating, dehumidifying, filtering, or a combination) to control environmental conditions within an enclosed space. Specifics on military ECU's may be found in References 27 and 32.

- Horizontal ECU - An ECU designed so that its maximum dimension is horizontal.
- Vertical ECU - An ECU designed so that its maximum dimension is vertical.

Equivalent diameter of a duct - One of the factors in determining pressure losses and resultant reductions in air flow is the circular equivalent of a rectangular duct. This is expressed in terms of the equivalent diameter of the rectangular section and can be computed using this formula:

$$\text{Equivalent diameter} = 1.3 \sqrt[8]{\frac{(ab)^5}{(a+b)^2}}$$

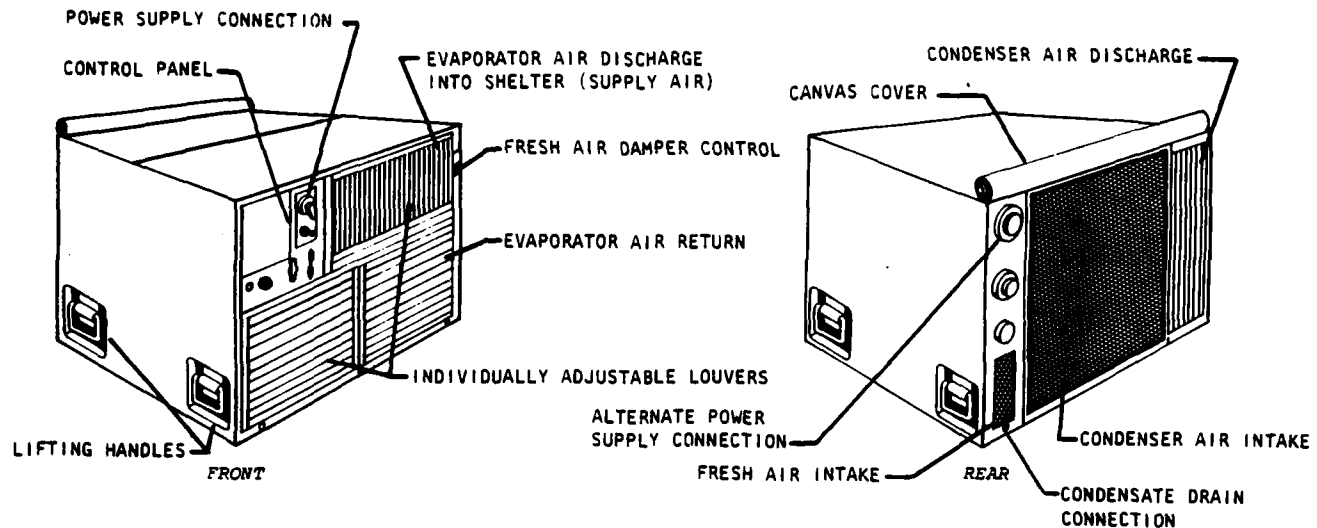
Where: a and b are the dimensions of two adjacent sides of the rectangle.

Gas Particulate Filter Unit (GPFU) - See Figure I-1-2.

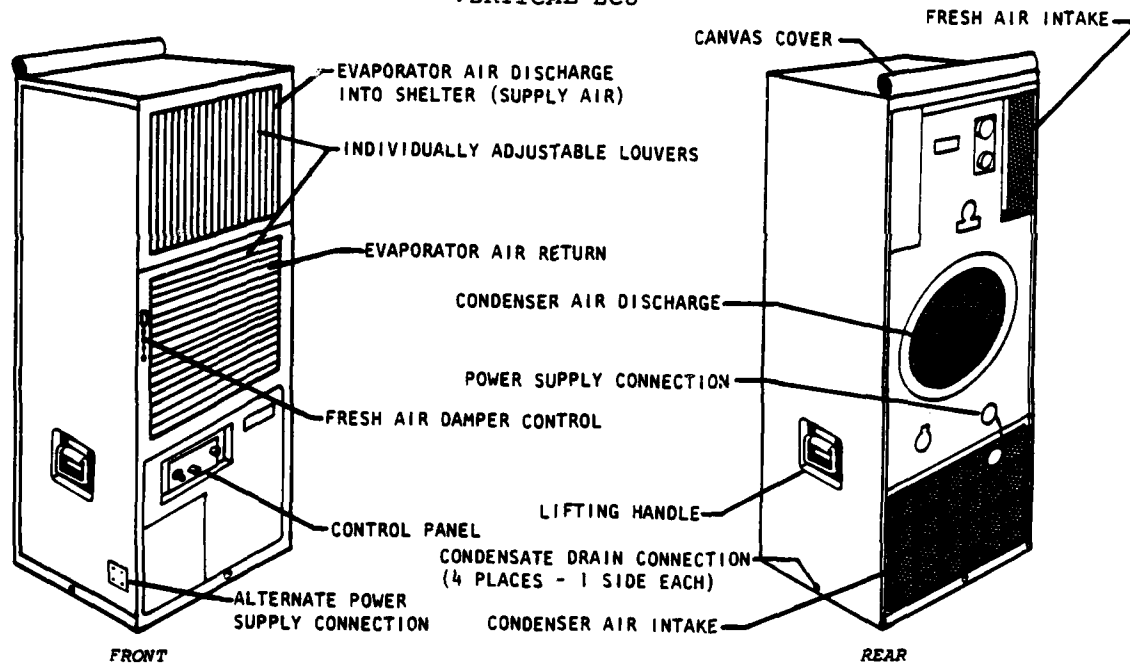
Heat gain - The rate at which heat enters into or is generated within an enclosed space.

Heat loss - The rate at which heat is transferred (lost) from an enclosed space.

HORIZONTAL ECU



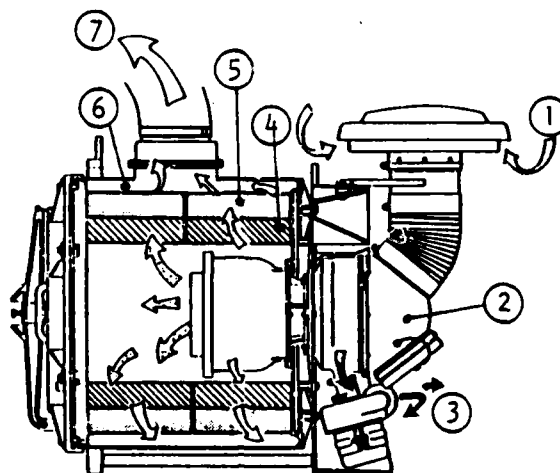
VERTICAL ECU



NOTE:

- AIR ENTERING THE CONDENSER AIR INTAKE COOLS THE CONDENSER AND LEAVES THROUGH THE CONDENSER AIR DISCHARGE. SINCE IT DOES NOT ENTER THE SHELTER, FILTERING IS NOT REQUIRED IN CB SITUATIONS.
- AIR (SUPPLY AIR) ENTERS THE SHELTER THROUGH THE EVAPORATOR AIR DISCHARGE. THERE ARE TWO SOURCES FOR SUPPLY AIR: AIR ALREADY IN THE SHELTER, WHICH IS TAKEN INTO THE ECU THROUGH THE EVAPORATOR AIR RETURN FOR RECONDITIONING, AND OUTDOOR AIR THROUGH THE FRESH AIR (MAKE-UP AIR) INTAKE. IN CB SITUATIONS THE FRESH AIR INTAKE IS OFTEN CONNECTED BY DUCTING TO THE GPFU AND ONLY FILTERED AIR IS PROVIDED. IF THIS IS NOT THE CASE, THE FRESH AIR INTAKE MUST BE CLOSED TO PREVENT LOSS OF SHELTER AIR PRESSURE. SEE THE DESCRIPTION OF THE MCPE-ECU INTERFACE ON PAGE V-5.

Figure I-1-1. TYPICAL MILITARY ENVIRONMENTAL CONTROL UNITS



GAS-PARTICULATE FILTER UNIT (GPFU) - A DEVICE WHICH PROVIDES CLEAN, FILTERED AIR AT SUFFICIENT RATE TO PERMIT THE BUILDUP AND MAINTENANCE OF A POSITIVE AIR PRESSURE IN A SHELTER. (ALSO SEE FIGURE V-2.) THE AIR ENTERS THROUGH THE PROTECTIVE CAP (1) AND IS ROUTED TO THE DUST SEPARATOR (2), WHICH REMOVES AND EXHAUSTS (3) 90 PERCENT OF THE DUST. THE AIR THEN PASSES THROUGH THE PARTICULATE FILTER (4), WHICH REMOVES PARTICULATE MATTER AND AEROSOLS, AND THEN THROUGH THE GAS FILTER (5) FOR REMOVAL OF GASEOUS TOXIC AGENTS. FROM THE FILTERS IT PASSES INTO A PLENUM (6) SURROUNDING THE FILTERS AND OUT THROUGH THE AIR OUTLET (7) TO THE ECU, SHELTER, AND PROTECTIVE ENTRANCE. THIS PROCESS RAISES THE AMBIENT AIR TEMPERATURE BY 10° TO 15°F. WHEN THE GPFU IS IN A DUST-FREE ENVIRONMENT OR WHEN MOUNTED 5 FEET OFF THE GROUND OR HIGHER IN A NORMAL ENVIRONMENT, IT MAY BE OPERATED WITHOUT THE DUST SEPARATOR.

Figure I-1-2. GAS PARTICULATE FILTER UNIT

Heat pump - To cite from Reference 35: "The heat pump is a mechanism that can either remove heat from an indoor area and discharge this heat to the outside, or it can be used to pick up heat from the outside and discharge it into the indoor area for heating." For details, see Reference 35.

- For heating, if the outdoor (evaporator) coil is operated at 0°F, for example, the refrigerant in the coil can pick up heat from ambient air at temperatures as low as 10° or 15°F. When compressed to 120° to 140°, the refrigerant will then release heat to cooler surrounding air being circulated to the shelter interior. Since the heat pump loses efficiency at lower temperatures, supplementary heaters are required to provide adequate heating capacity and are normal components of the unit.

- For cooling, the heating process is reversed by the use of a system of valves (e.g., the outside evaporator becomes the condenser) and the heat pump then functions basically as a normal air conditioner.

- The Navy heat pumps as now available are adaptations of Westinghouse commercial models and were not designed with tactical environments in mind. (See Figure I-1-3.) They lack the ruggedness and durability under field conditions of the ECU's designed for military applications. When they are transported, it should be on smooth roads with the avoidance of shocks. The compressor of a wall-mounted unit failed in a recent road test which was less severe than railroad humping. Therefore, if subjected to cross-country road conditions or railroad humping, experience has shown that they can be expected to fail internally unless carefully packed and braced externally and internally. However, in peacetime, static situations they offer an additional range of options for environmental control.

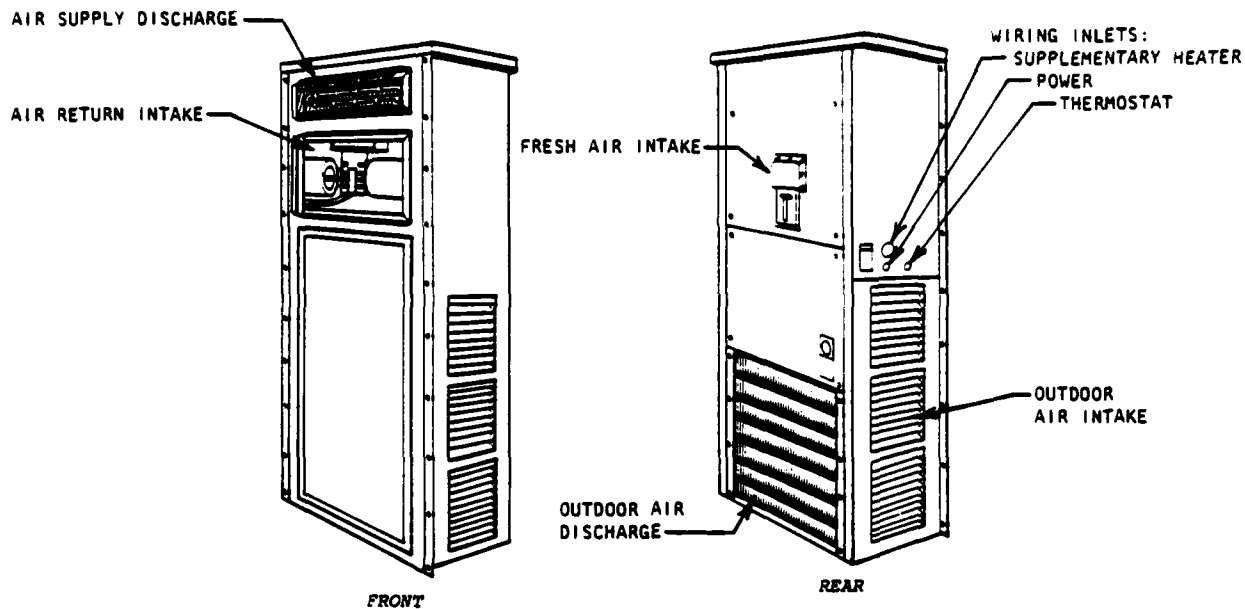
Heating capacity - The measure of the ability of an ECU or heater to add heat to an enclosed space.

Heating load - The rate at which heat must be added to an enclosed space to maintain a given inside temperature.

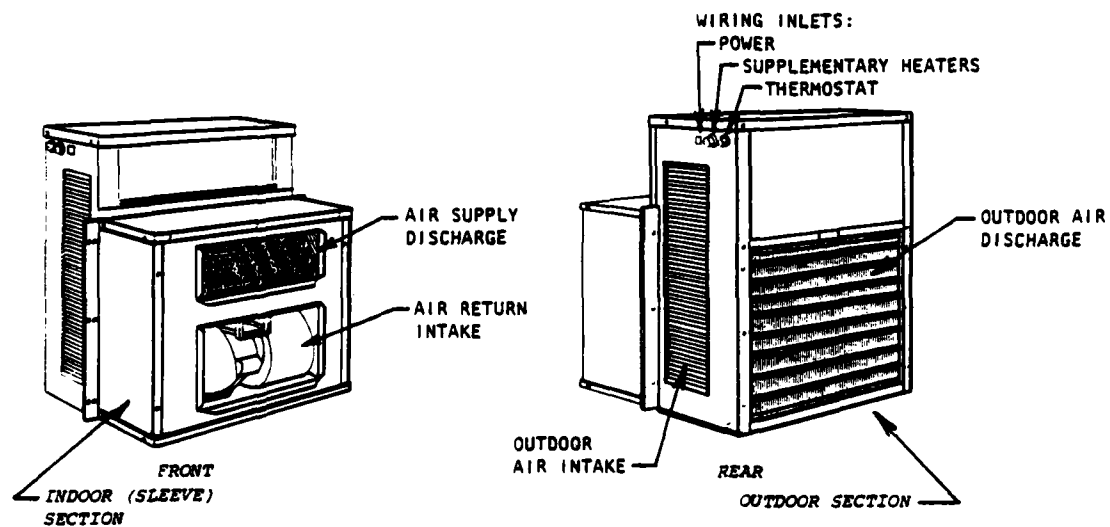
Modular Collective Protection Equipment (MCPE) - A system of interacting modules necessary in a CBR environment to provide clean, filtered air to a shelter, to maintain a small positive air pressure in the shelter to prevent outside-to-inside leakage of contaminants, and to permit entry and exit of personnel without contaminating the shelter interior. The MCPE probably will operate in conjunction with an ECU. More description and illustration may be found in paragraph V-4 and Figure V-1, Section V.

Plenum - Basically, a large duct. One use is similar to an automotive engine manifold, that is, to collect air from more than one source before distributing it to one or more outlets. In another use, it is a wide duct with many small openings for air passage. It might cover an entire ceiling and distribute the air through the many outlets over the area. Plenums distribute air usually more gently and more quietly than more finite outlets but lack ability for precise regulation of flow and direction. A plenum may also be used for return air.

WALL-MOUNTED UNIT, HBO36 AND HB022



SLEEVE (THROUGH-WALL)-MOUNTED UNIT, HE036R&S AND HE022R&S



NOTE:

- UNITS ARE TO BE USED WITH DUCTING THEREFORE HAVE NO ATTACHED GRILLES FOR THE INDOOR SUPPLY AND RETURN.
- UNITS ARE CONTROLLED BY THERMOSTAT MOUNTED ON SHELTER INTERIOR WALL.

Figure I-1-3. NAVY HEAT PUMPS

Short circuit - A term used to describe the condition in which the supply air goes directly back into the return almost as soon as it is discharged. This is caused most often when an obstacle is too close in front of the supply and return outlets, retarding the proper flow of air. This might also occur when the obstacle blocks the return, leaving the return air no path other than across or through the supply flow. Remedies include relocating the obstacle, relocating the obstruction, or ducting the supply to where it is clear of the obstruction.

Throw - The horizontal distance that air will travel after it leaves the supply discharge before a specified reduced velocity, usually 50 feet per minute, is reached.

Ventilation - The process of introducing ambient air into an enclosed space by an ECU.

APPENDIX I-2. BIBLIOGRAPHICAL REFERENCES

1. Aluminum Association, The, Aluminum Construction Manual, Section 3, Engineering Data for Aluminum Structures, third edition, 1975.
2. Aluminum Company of America, ALCOA Structural Handbook, Pittsburgh, Pennsylvania: ALCOA, 1960.
3. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., ASHRAE Handbook and Product Directory, 1979 Equipment, New York, N.Y.: ASHRAE, 1979.
4. _____, ASHRAE Handbook, 1981 Fundamentals, Atlanta, Ga.: ASHRAE, 1981.
5. Anonymous, Installation Manual for Adaptor Kit, Remote Control Conversion, 18K Vertical Air Conditioner for AN/TSC-26 System, 1970.
6. _____, Methods for Installing the 18,000 Btuh Total Environmental Control System in Trailers and Shelters, 1974.
7. Carrier Air Conditioning Company, Carrier System Design Manual, Part 2, Air Distribution, Seventh Printing, Syracuse, N.Y.: Carrier Air Conditioning Company, 1966.
8. Engineering Laboratory, Computer Sciences Corporation, National Space and Technology Laboratories, NSTL Station, Mississippi, Chemical and Biological Protective Equipment Guidelines for Modular Collective Protection Equipment User Systems, Chemical Systems Laboratory Contractor Report, 1981. (Requests for document should be made to: Commander/Director, Chemical Systems Laboratory, ATTN: DRDAR-CLJ-R, Aberdeen Proving Ground, Maryland 21010.)
9. Glasstone, Samuel and Philip J. Dolan, ed, The Effects of Nuclear Weapons, U.S. Department of Defense and the Energy Research and Development Administration, Washington, D.C.: U.S. Government Printing Office, 1977.
10. ITEM 1978 (Interference Technology Engineers Master) Directory and Design Guide, Plymouth Meeting, PA, R&B Enterprises, 1978.
11. Krisko, William J., Study on Sealing and Leakage Reduction Measures for CB Protective Shelters, Corad Division, Donaldson Company, Inc. for Physical Protection Laboratory, Edgewood Arsenal, MD, 1970.
12. Baumeister, Theodore, ed, Marks' Mechanical Engineers' Handbook, sixth edition, New York: McGraw-Hill Book Company, 1964.
13. Mears, Merton D., Special Publication ARCSL-SP-79003, Handbook on Collective Protection, Aberdeen Proving Ground, MD: Chemical Systems Laboratory, U.S. Army Armament Research and Development Command, 1979. (Requests for document should be made to: Commander/Director, Chemical Systems Laboratory, ATTN: DRDAR-CLJ-R, Aberdeen Proving Ground, Maryland 21010.)

14. Metex Electronic Shielding Group, EMI/RFI Shielding Handbook and Catalog, Edison, N.J.: Metex Corporation, 1977.
15. Quadripartite Standardization Agreement-360. Climatic Environmental Conditions Affecting the Design of Military Materiel, Armies of the United States, United Kingdom, Australia, and Canadian Forces, 1979.
16. Schuman, William J., Jr., E. James Gaul, David F. Bassett, Robert K. Warner; U.S. Army Harry Diamond Laboratories, Hardened NBC Protection for C³ Shelters (undated).
17. Schuman, William J., Jr., U.S. Army Harry Diamond Laboratories; Garabed Zartarian and Raffi P. Yeghiayan, Kaman Avidyne; W. Don Allison, U.S. Army Ballistics Research Laboratory, C³ Shelter Designs for the Tactical Battlefield (undated).
18. Spectrum Control, Inc., Spectrum Control Catalog (a catalog of products and services related to electromagnetic compatibility), Fairview, PA, undated.
19. Trane Company, Trane Refrigeration Manual (Manual 2), LaCrosse, Wisconsin: Trane Company.
20. U.S. Department of the Army, Army Materiel Command, AMC Pamphlet No. 706-120, Engineering Design Handbook, Criteria for Environmental Control of Mobile Systems, Washington, D.C.: U.S. Government Printing Office, 1971.
21. _____, Army Regulation No. 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 1 August 1979 with Change 1, 15 September 1979.
22. _____, Chemical Systems Laboratory, Aberdeen Proving Ground, Maryland 21010, Air Filtration by Modular Collective Protection Equipment, Aberdeen Proving Ground, MD, 1981.
23. _____, Technical Manual, TM 5-3610-250-14, Operator, Organizational, Direct Support and General Support Maintenance Manual for Map Layout Section, Topographic Support System, Semi-Trailer Mounted (Gichner Mobile Systems Model 10536-1), Jan 1981.
24. _____, Technical Manual, TM 750-5-15, Army Equipment Data Sheets, Chemical Weapons and Defense Equipment, August 1972.
25. U.S. Department of Defense, DOD Brochure: Standard Family of Tactical Shelters, Natick, MA: U.S. Army Natick Research and Development Laboratories, 1981.
26. _____, DOD Military Handbook, MIL-HDBK-23A, Structural Sandwich Composites, U.S. Air Force, Dec 1968 with changes through Jun 1974.

27. _____, _____, Military Specification, MIL-A-52767B, Air Conditioners: Vertical and Horizontal, Compact, 4 Sep 1979 with interim Amendment, 8 Jul 1981.
28. _____, _____, MIL-S-55286D, Shelter, Electrical Equipment S-280()/G, 5 Dec 1979.
29. _____, _____, MIL-M-81957A(AS), Mobile Facility, General Specification For, 9 Oct 1975.
30. _____, _____, MIL-C-83400A, Core Material for Metal Sandwich Panels for Shelter Construction (Polyurethane Foam), 19 Aug 1980.
31. _____, Military Standard, MIL-STD-1407, Heaters, Vehicular Compartment; Heaters, Coolant, Engine; Heaters, Space; Heaters, Duct-Type, 16 Jul 1975.
32. _____, _____, MIL-STD-1408A, Air Conditioners, Family of Environmental Control Units, General Application Characteristics, 9 Apr 1975.
33. _____, _____, MIL-STD-1472C, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 2 May 1981.
34. _____, Military Standardization Handbook, MIL-HDBK 5C, Metallic Materials and Elements for Aerospace Vehicle Structures, Vol I, 15 Sep 1976.
35. U.S. Navy Technical Manual, NAVAIR 19-60-83, Air Conditioner/Heat Pumps, Models HB036, HE036, HB022 and HE022 (Westinghouse Air Conditioning, Sturtevant Division), Naval Air Systems Command, 1980.

APPENDIX II-1. ESTIMATING SHELTER COOLING AND HEATING REQUIREMENTS

II-1-1. Purpose

This appendix explains how the methods you used in Worksheet Parts I and II were developed.

WORKSHEET PART I

II-1-2. Cooling Requirement Estimate

You determine the total cooling load for a shelter by summing the heat gains from solar radiation and conduction (Step 1), electrical equipment and lights (Step 2), personnel occupying the shelter (Step 3), and the ventilation air drawn in from outside (Step 4).

• Step 1: Summer Heat Gain From Solar Radiation and Conduction. This part of the total cooling load is the Btuh to be gained under the design conditions (Figure II-1, Column C) adjusted to a specific climate using the multiplier of Column E. This is how these are derived:

•• Column C. Compute the shelter summer heat gain from solar radiation and conduction, Column C, using the cooling load temperature difference (CLTD) method described in Chapter 26 of the 1981 ASHRAE Handbook (Reference 4). This method applies the following relationship:

$$q = U \times A \times CLTD$$

Where: q = Cooling load (heat gain) in British thermal units (Btu) per hour.

U = Heat transfer coefficient of the shelter in Btu per hour (Btuh) per square foot (SF) per degree Fahrenheit (°F). For the Navy MF shelters it is taken as 0.25 Btuh/SF/°F and for all other shelters it is taken as 0.35 Btuh/SF/°F.

A = Area in SF of the surface (wall, roof, floor) of the shelter for which the q is being computed.

CLTD = Cooling load temperature difference in °F from Chapter 26 of the 1981 ASHRAE Handbook:

-- Roof 1, without suspended ceiling, Table 5A, worst case.

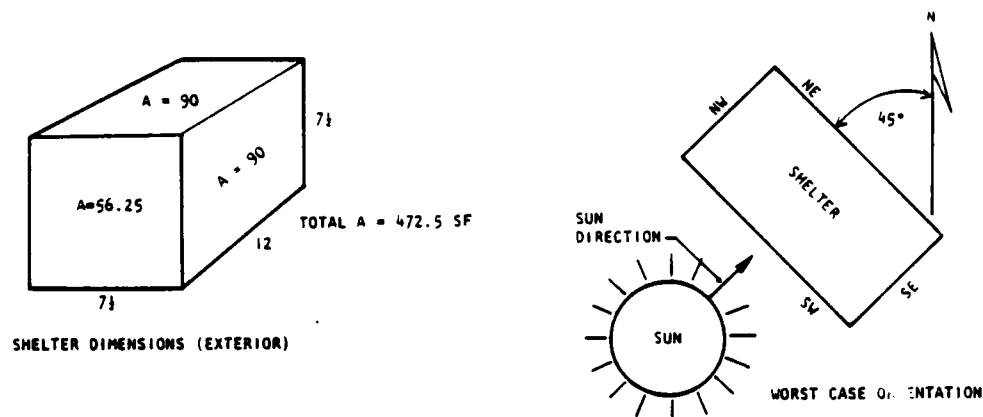
-- Wall, Group G, Table 7A, worst case.

(Both tables based upon an inside design temperature of 78°F¹ and minimum outside temperature of 95°F²).

Note: For the floor, because the sun never reaches the floor, the CLTD is:

$$95^{\circ} - 78^{\circ} = 17^{\circ}\text{F}$$

An example of the above relationship using the S-280 shelter:



Computations:

Element	U-Factor	x	Area	x	CLTD	=	q
Walls - NE	0.35	x	90	x	26	=	819.0
- SE	0.35	x	56.25	x	30	=	590.6
- SW	0.35	x	90	x	63	=	1,984.5
- NW	0.35	x	56.25	x	47	=	925.3
Roof	0.35	x	90	x	70	=	2,205.0
Floor	0.35	x	90	x	17	=	535.5
Total						=	7,059.9 Btuh

•• Column E. The summer cooling load in Column C, Figure II-1, was based on areas where the maximum summer temperature is 95°F. For other areas the adjustment factors of Column E are needed. Develop the Column E factors as follows:

¹78°F (dry bulb) is the neutral point between sensations of being warm and cool in the ASHRAE Comfort-Health Index (Reference 4, Chapter 8). This is also the inside temperature used in the ASHRAE CLTD tables (Reference 4, Chapter 26) upon which the data in Columns C through F of Figure II-1 are based.

²The ASHRAE CLTD tables and, consequently, the values in Columns C and D of Figure II-1, are based upon an outside design temperature of 95°F (DB).

The ASHRAE Handbook (Chapter 26) provides a formula for a corrected CLTD:

$$CLTD_{corr} = [(CLTD + LM) \times K + (78 - T_R) + (T_o - 85)] \times f$$

Where: CLTD is the same as previously used.

LM is a latitude-month correction which is not required here.

K is a color correction factor which equals 1 since there is no color change.

(78 - T_R) is the indoor design correction which is not required here since indoor design temperature remains the same.

($T_o - 85$) is the outdoor correction factor. T_o is the average outside temperature from Figure I-3. The 85°F is the mean outdoor temperature upon which the tables in Chapter 26, 1981 ASHRAE Handbook, are based.

f is a factor for an attic fan and is not applicable.

The resulting formula is:

$$CLTD_{corr} = CLTD + (T_o - 85)$$

Using climatic category A1 and the S280 figures from above for the example:

Element

NE	0.35	x	90	x	(26 + (105-85))	=	1,449
SE	0.35	x	56.25	x	(30 + (105-85))	=	984.38
SW	0.35	x	90	x	(63 + (105-85))	=	2,614.5
NW	0.35	x	56.25	x	(47 + (105-85))	=	1,319.06
Roof	0.35	x	90	x	(70 + (105-85))	=	2,835
Floor	0.35	x	90	x	(120 - 78)	=	<u>1,323</u>

Total = 10,524.94 Btuh

(Use: 10,525 Btuh)

The adjustment factor for Column E is the ratio of the adjusted cooling load (heat gain) to the design conditions cooling load

$$= \frac{10,525 \text{ Btuh}}{7,050 \text{ Btuh}} = 1.49$$

• Step 2: Heat Gain from Electrical Equipment and Lights.

Operating electrical equipment, electrical motors, and lights are sources of shelter heat gain. Reference 12 (Appendix I-2) offers the figure 3.4 Btuh per Watt for converting the total electric power to heat. So add the power rating of all electrical equipment in the shelter and multiply by 3.4 to obtain the estimated heat gain from this source.

• Step 3: Heat Gain from Personnel Occupying the Shelter.

People are sources of both sensible heat and latent heat (moisture). The heat gain to the shelter depends upon the level of activity and sex of the occupants. Table 18 in Chapter 26 of the 1981 ASHRAE Handbook (Reference 4) shows that for a seated male doing very light work the heat gain is 480 Btuh. For purposes of this handbook, this value is rounded to 500 Btuh. Therefore, the number of people occupying the shelter is multiplied by 500 to determine the total heat gain from personnel.

• Step 4: Heat Gain from Ventilation. This part of the total heat gain depends upon the volume of air introduced into the shelter, inside and outside temperature, and inside and outside humidity.

•• The total heat gain from ventilation is found when you multiply the total cfm of air brought into the shelter by the climatic area factor from Column G (summer) or H (winter) of Figure II-1. This factor is a function of temperature and humidity and is developed from formula (33) on page 26.30 of Reference 4:

$$Q_t = 4.5 \times \text{cfm} \times \Delta h$$

Where: Q_t = heat gain in Btuh per cfm

4.5 = 60 min/hr x 0.075 lb of dry air/cu ft. This converts cfm to lb of dry air/hour.

cfm = the quantity of outside air introduced into the shelter/min.

Δh = difference between inside enthalpy (h_i) and outside enthalpy (h_o) in Btu/lb = ($h_i - h_o$).

•• Reference 33 established a military design requirement for ventilation of 20 cfm outside air per person. You multiply this by the number of occupants in the shelter to determine the total volume (cfm) of air to be brought into the shelter per minute. This is the cfm to be used in the above formula. The $4.5 \times \Delta h$ then becomes the formula for the factors, q, of Columns G and H, Figure II-1.

$$\text{Or: } q = 4.5 (h_i - h_o)$$

•• To determine h_i and h_o :

FOR SUMMER COOLING

(For the summer cooling example, Climatic Category A1 is used.)

T_o = outside temperature = 120°F DB (see Figure I-3)

T_i = inside temperature = 78°F DB (see footnote 1, page II-1-2)

RH_o = outside relative humidity = 3% (see Figure I-3)

Using T_o and RH_o , enter the ASHRAE Psychometric Chart No. 1 and find:

$$h_o = 31.2 \text{ Btu/lb dry air}$$

$$w_o = 0.002 \text{ lb water/lb dry air}$$

Assume no change in air moisture content between outside and inside.¹
Therefore:

$$w_i = w_o = 0.002 \text{ lb water/lb dry air}$$

Using T_i and w_i , enter the psychometric chart and find:

$$h_i = 21 \text{ Btu/lb dry air}$$

Then:

$$q = 4.5 (31.2 - 21)$$

$$= 45.9 \text{ Btuh/cfm}$$

Use: 46 Btuh/cfm (see Figure II-1)

FOR WINTER HEATING

(For the winter heating example, Climatic Category C0 is used.)

T_o = 0°F (see Figure I-3; round (-)20°F to 0°F for this purpose)

T_i = 70°F (see Figure II-1 and Reference 4, Chapter 25)

RH_o = 100% (see Figure I-3)

¹This is a safe assumption under low humidity conditions. In higher humidity areas (e.g., B2), it is assumed that the ECU will remove half the moisture from the outside air; therefore, $w_i = 0.5w_o$.

Using T_o and RH_o , enter ASHRAE Psychometric Chart No. 2 and find:

$$h_o = 0.85 \text{ Btu/lb dry air}$$

$$w_o = 0.0008 \text{ lb water/lb dry air}$$

Assume: $w_i = w_o = 0.0008 \text{ lb water/lb dry air}$, enter ASHRAE Psychometric Chart No. 1 with w_i and T_i and find:

$$h_i = 17.8 \text{ Btu/lb dry air}$$

Then: $q = 4.5 (17.8 - 0.85)$

$$= 76.3 \text{ Btuh/cfm}$$

Use: 76 Btuh/cfm (see Figure III-1)

WORKSHEET PART II

II-1-3. Heating Requirements Estimate

Determine the total heating requirements in the same way that you found the cooling requirement. The methods as well as the multipliers for computing heat gains from electrical equipment and personnel in the shelter (Steps 9 and 10) and the heat loss from ventilation (Step 7) are identical to the corresponding functions in the cooling estimate. Therefore, the bases for Worksheet Part II Steps 7, 9, and 10 do not need to be explained again. The conduction heat loss requires slight modifications to the Part I formula; this is addressed below.

• Conduction Heat Loss (Load), Figure II-1, Column D. The relationship used in paragraph II-1-2 applies here also but with a modification:

$$q = U \times A \times T$$

Where: q , U , and A are the same as in paragraph II-1-2.

T represents the difference between the design inside temperature (70°F) and the outside ambient temperature (0°F). This is used instead of CLTD, which includes solar radiation transfer, since maximum heat loss occurs at night when there is no solar radiation. Further, since there is not sun at night, orientation is immaterial and A equals the entire shelter outside area.

Still using the S-280 Shelter for the example computation:

$$q = 0.35 \times 472.5 \times (70 - 0) = 11,576 \text{ Btuh}$$

(Use: 11,580 Btuh)

• Winter Heating Factor, Figure III-1, Column F

$$\begin{aligned} q &= U \times A \times T_{\text{corrected for C1 condition}} \\ &= 0.35 \times 472.5 \times (70 - (-25)) \\ &= 15,711 \text{ Btuh} \end{aligned}$$

II-1-4. Verification. To verify the validity of broad application of the adjustment factor in both Columns E and F, computations were done individually for each shelter and all were found to agree.

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INTEGRATION ENGINEERING HANDBOOK FOR ENVIRONMENTAL
CONTROL(U) RADIAN INC ALEXANDRIA VA P A JORDAN
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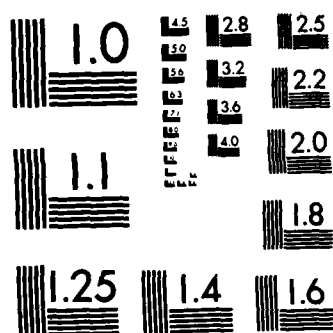
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APPENDIX II-2. REDUCING COOLING LOAD BY SHADING

II-2-1. Introduction

Solar radiation is a significant source of heat gain for a shelter. This appendix presents the method which was used to estimate how much reduction in heat gain, and resultant cooling load, from this source can be achieved by shading the shelter. The example presented is for the S280 shelter. The method will work for other shelters, as well. In fact, the 45 percent approximate reduction given in paragraph II-12, Section II, is an approximation derived from the estimated reductions using several representative types of shelters.

II-2-2. Starting Point

- S280 shelter, with same orientation relative to the sun as was used in Appendix II-1. Dimensions and orientation are shown on page II-1-2.

- Since all shelter surfaces will be shaded, the CLTD will be 26°F; this is the same as for the NE wall in Appendix II-1, which is away from the sun (see page II-1-2).

- The cooling load for the unshaded shelter does not exceed the load for the shaded shelter until after 0900 to 1000 hours.

- The sun altitude is below 45° from vertical only two or three hours before 0900 to 1000 hours. Therefore, a shading angle of 45° is adequate. See Figure II-6.

II-2-3. Computations

- For S280 Shelter:

<u>Element</u>	<u>U-Factor</u>	X	<u>Area</u> ¹	X	<u>CLTD</u>	=	<u>q</u>
Walls - NE	0.35		90		26	=	819.0
- SE	0.35		56.25		26	=	511.9
- SW	0.35		90		26	=	819.0
- NW	0.35		56.25		26	=	511.9
Roof	0.35		90		26	=	819.0
Floor	0.35		90		17	=	<u>535.5</u>

Shaded Total 4016.3 BTUH

Unshaded Total: 7,059.9¹

Shaded Total: 4,016.3

Difference: 3,043.6 BTUH

$\frac{3,043.6}{7,059.9} \times 100 = 43\% \text{ Reduction}$

• By the same method, heat gain reductions for other representative shelters were estimated at approximately 45% plus or minus 3%. Since consistent precision and constant conditions are not possible when working with matters of this nature, the figure of 45% for reduction in solar heat gain from shading is taken as a valid and useful standard reduction for application to all shelters.

¹From page II-1-2.

APPENDIX III-1. RETRACTABLE MOUNT DESIGN

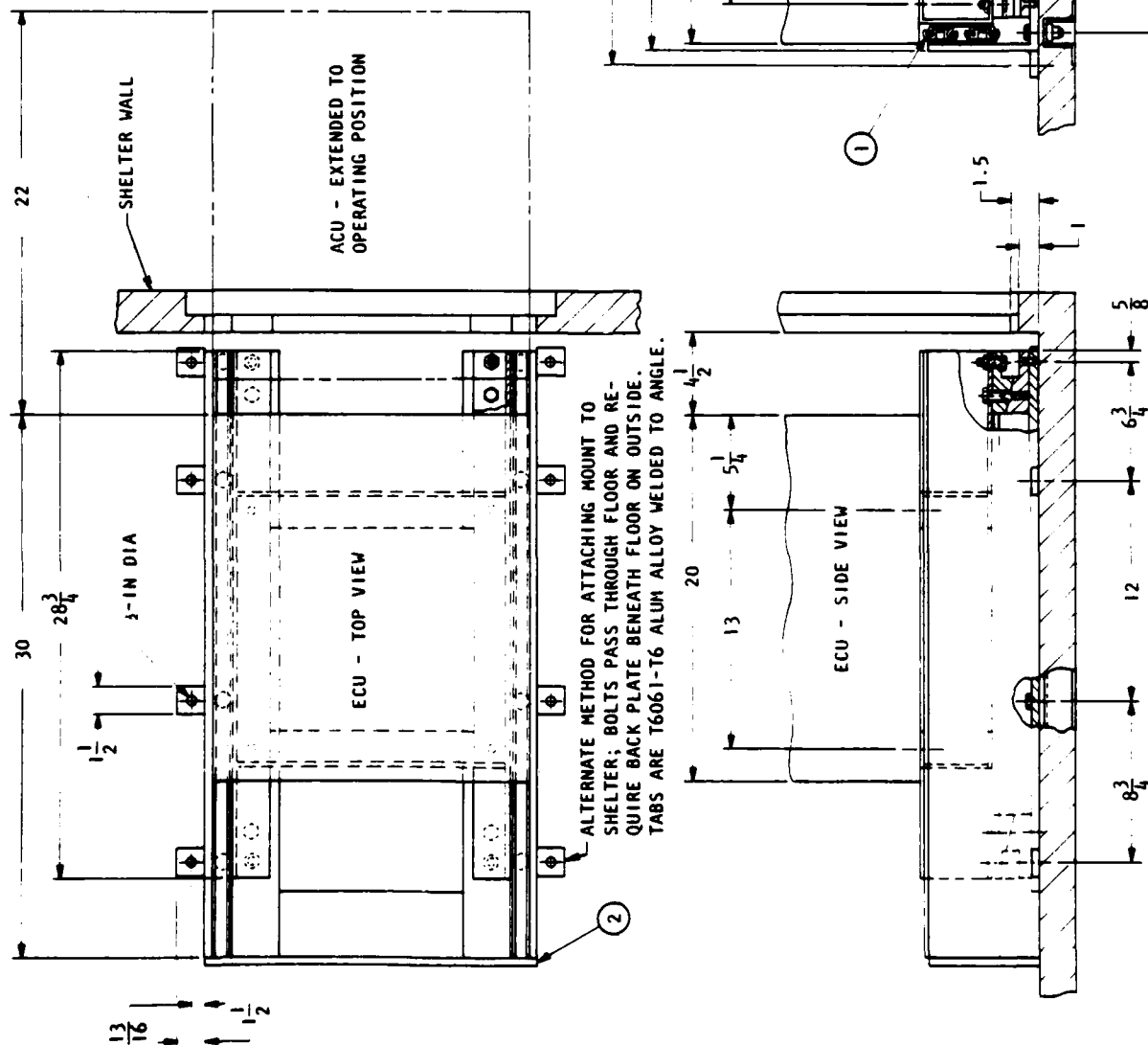
Content

This appendix contains a design for a retractable mount for one 18,000 Btuh military vertical ECU. The design was drawn with the S280 shelter in mind but is adaptable to other shelters as well as to other ECU's. If heavier ECU's are contemplated, heavier duty tracks will be required. (Check the weight of ECU against track manufacturer's claims for track carrying capacity.) Also, the provisions for anchoring the ECU for transit should be re-evaluated. As for all designs in this III-series of appendices, shop drawings must be provided before the mount can be fabricated.

FIND NO.	QTY	DESCRIPTION
1	2	Angle, 6 x 4 x $\frac{7}{16}$, 4.91 lb/ft
2	1	Angle, 6 x 4 x $\frac{7}{16}$, 4.91 lb/ft
3	2	Channel, Army-Navy, 4 x 2, 2.205 lb/ft
4		Channel, Army-Navy, 4 x 2, 2.205 lb/ft
5	2	Slim track, 2-section ball bearing slides. May be obtained from Barnes Engineering Company, Anaheim, CA, Model HD-282-30 or comparable item from other manufacturer.

NOTES:

1. Find No. 1 thru 4 are 6061-T6 aluminum alloy.
2. All dimensions are in inches.
3. All bolts 1-13UNC SAE with hex nuts unless otherwise indicated.
4. Space mounting holes on center-to-center spacing of outboard hat sections.



III-1-2

NOTE 4.

Figure III-1-1. RETRACTABLE FLOOR MOUNT FOR VERTICAL 18,000 BTUH ECU

APPENDIX III-2. SAMPLE CALCULATIONS: STRESS ANALYSIS
FOR WALL MOUNTING FRAME FOR 36,000 BTUH
ECU ON S280 SHELTER

III-2-1. Introduction.

The task here is to develop mounting frames which allow the standard, compact, horizontal 9000, 18000, and 36000 Btuh ECU's to be attached, singly or in pairs to small, transportable shelters. The frames must be simple yet sufficiently strong to support the units during railroad transportation and when subjected to limited nuclear overpressures (up to 4 psi). The task includes only horizontal ECU's. The horizontal configuration is more suited to fixed mounting on the front end of a truck-mounted shelter, such as the S280, and can fit above a truck cab. The sample calculations presented in later paragraphs are for the 36,000 Btuh horizontal ECU and are representative and illustrative of the method employed for all sizes of units.

• The Shelter

The design considers only the Army S280 shelter, which is similar in end dimensions and construction features to most other unhardened and non-expandible shelters. You should, therefore, be able to adapt mountings designed for the S280 to other shelters of similar dimensions fairly easily.

•• The S280 has outside dimensions of 7-1/2 feet in height x 7-1/2 feet in width x 12 feet in length. It weighs about 1400 pounds and uses sandwich construction for the wall, roof, and floor panels.

•• The wall panels, to which the ECU's must be attached, consist of a 2-inch thick urethane foam core (density 2 pcf) to which 0.040-inch thick sheets of 5052-H34 aluminum alloy have been cemented on both inside and outside surfaces. Although the panels are formed with aluminum extrusions on the edges and are stiffened with aluminum extrusions placed inside the panel, exploratory calculations indicated that it would not be feasible to transfer the dynamic loads due to railroad humping directly to the composite wall. The lack of compressive and shear strength of the low-density urethane foam core is the limiting factor. Discussions with a representative of a firm¹ which manufactures urethane foam disclosed that the foam would have to be much denser, about 16 pcf, to have the shear and compressive strengths necessary for a structural component in a composite wall. Material with the density of only 2 pcf is primarily a thermal insulation, according to the manufacturer.

•• Two leading shelter manufacturers² advised that the shelter end panel probably would not stand up to the design loadings (see next single-bullet paragraph), especially for the heavier ECU's, unless the panel were specifically constructed for the loads. They further said that it would be risky to fit a standard mounting frame to an end panel without the aid of the structural drawings for the particular shelter being used since the structural design of shelters is not uniform; the size, placement, and number

¹Plastics Manufacturing Company, Philadelphia, Pennsylvania.

²Craig Systems and Gichner Mobile Systems.

of stiffeners is not assured even within a given shelter type and model. They therefore recommended transferring some of the loads to the side and roof panels which, in shear, can take them better than the end panel can be expected to take them in moment. The fact that the mount designs do not rely specifically on the panel stiffeners for strength or bolted attachments makes it easier to adapt the mounts to a variety of end panel designs.

●● Paper honeycomb is a much stronger core material than 2 pcf urethane. For this reason, shelter panels with paper honeycomb cores³ do not have internal stiffeners. The result is that the panel strength is comparable to urethane panels, and the ECU mounting frame attachment and load transfer are also comparable. The same mounting frame designs are adaptable to both urethane and paper honeycomb panels and no design was made specifically for either one.

●● As mentioned above, the mounting frames are designed to survive limited nuclear overpressures. To exploit this capability, they must be attached to shelters hardened to a comparable degree. When attached to an unhardened shelter, the frame would survive only as long as the shelters does. Nevertheless, the mounting frames have been designed to be adaptable to either the hardened or unhardened shelter. The HATS program is supposed to include designs for mountings hardened to the same level as the shelter.

● Dynamic Loads.

●● Transportation Shocks. In addition to the weight of the units, the frames must be capable of supporting the ECU's when subjected to the following acceleration forces caused by railroad humping:

Longitudinal direction	- 10g's acceleration
Transverse direction	- 6g's acceleration
Vertical direction	- 6g's acceleration

These figures were used in the calculation set of Reference 6.

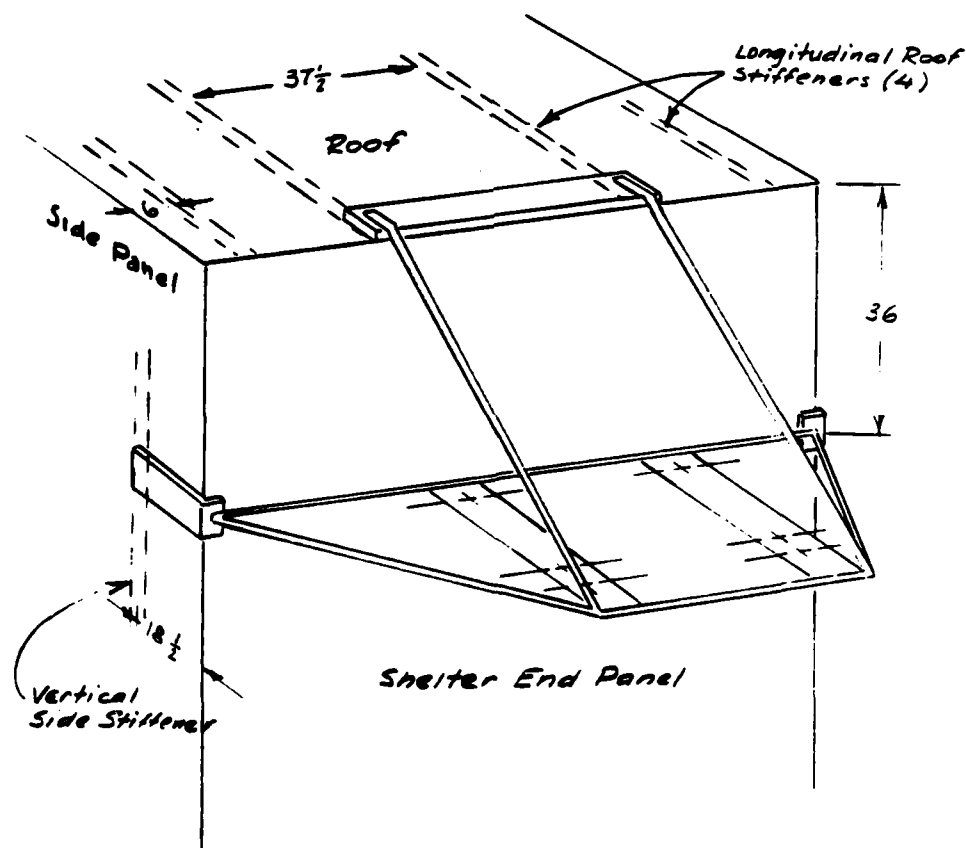
●● Nuclear Overpressure. The criteria presented in References 16 and 17 indicate that a shelter should be able to withstand a peak free-field overpressure of 7.3 psig, which translates to an amplified peak reflected overpressure of 35 psig equivalent static load. An unhardened shelter would not hold up to this (nor would the mounts presented in this handbook.) For more discussion of this, see paragraph VII-2.

●● No test data are available to show whether the ECU, itself, can withstand the dynamic loads described above. This is a source of some concern. Design criteria specify that ECU's be able to withstand railroad humping and it is assumed that they are being manufactured in accordance with the specifications. However, the nuclear overpressure loading at 7.3 psi is worse than the humping loads and it is highly unlikely that the ECU's, without extensive protective measures, would survive it.

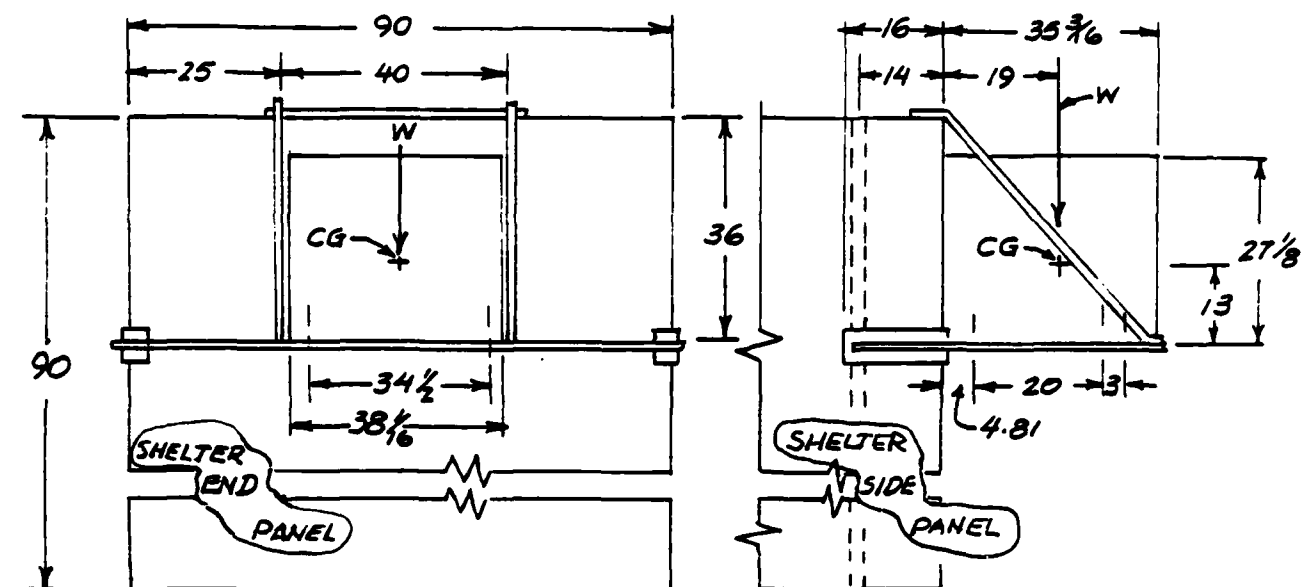
³Brunswick Shelters, for example.

• Allowable Stresses. To facilitate the design, we decided to apply a minimum factor of safety of 2.5 on the appropriate yield properties of the material, using the railroad humping loads. This would provide ample protection for the humping loads (factor of safety = 2.5 on yield stress) and limited resistance to nuclear blast pressure.

• Concept of Design. These designs are for securing: a single 18,000 Btuh horizontal ECU to the shelter front end (adaptable for a 9,000 Btuh unit); two 18,000 Btuh horizontal ECU's (adaptable for two 9,000 Btuh units); and a 36,000 Btuh unit. Two of the designs, for the single 18,000 Btuh unit and for two 18,000 Btuh units, use structural elements secured to the corners of the shelters. The vertical location of the two mounts can be shifted up or down to meet the needs of the application. The design for the 36,000 Btuh has its location fixed near the top of the end panel by the two diagonal struts used to transfer some of the loads to the roof panel of the shelter. This concept is sketched below. This design for the 36,000 Btuh ECU mounting is the one used in the following paragraphs to illustrate the stress analysis method employed for all designs.



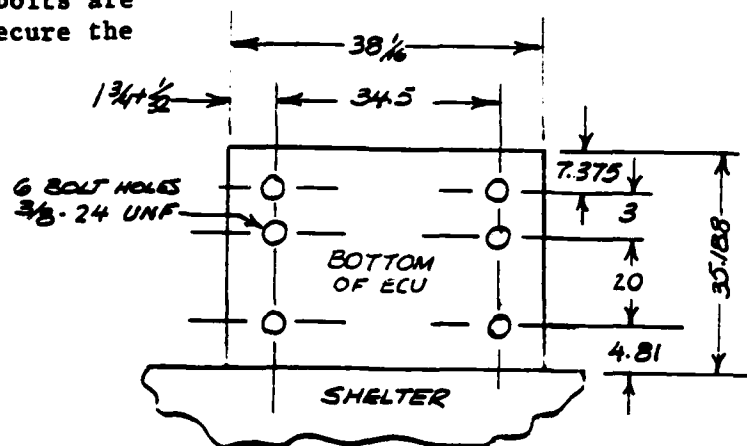
• Dimensions and Weight.



Weight, $W = 435$ lb.

• ECU Mounting Bolt Spacing.

Six 3/8-inch diameter bolts are used in the bottom of the ECU to secure the unit to the mounting frame.



• Stress Analysis Approach and Sequence of Broad Steps.

With the design concept decided (see the sketch on page III-2-4), we then determine the shape and size of each member of the mounting frame based upon the stresses expected in each member. Aluminum is used throughout to save weight; section characteristics and allowable stresses are taken from Reference 1.

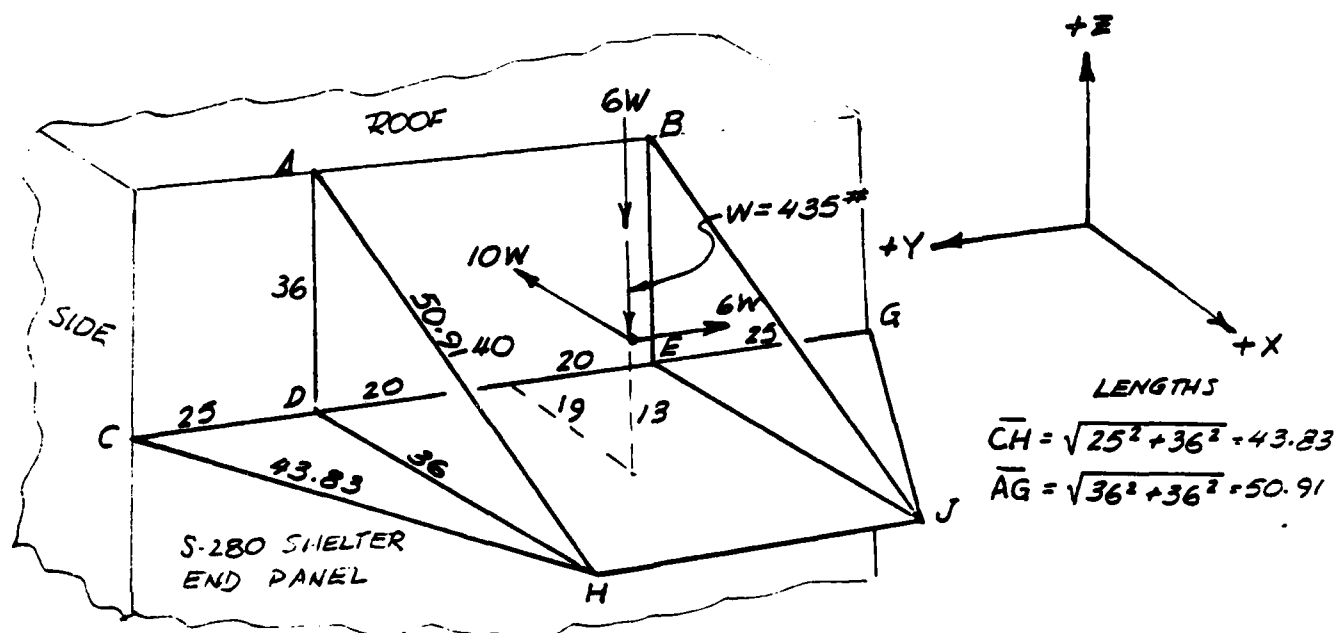
•• We assume that the frame is weightless and exerts no forces upon itself. This eases the computations and is made acceptable by the factor of safety which is applied.

•• Our first broad step determines the reactions to the design loadings at the connections of the mounting frame to the shelter and establishes the design conditions for these connections (paragraph III-2-2).

•• The next broad step (paragraph III-2-3) determines the ECU mounting bolt reactions to the design loadings.

•• In the last broad step, we use the reactions previously determined, to find the forces and moments acting on the members of the mounting frame (paragraph III-2-4). We then select each member from the standard shapes of Reference 1 to withstand these forces and moments.

III-2-2. Frame-to-Shelter Attachment Bolt Reactions at Points A, B, C, and G. These are reactions to the humping loads (shocks) in the three primary directions. The maximum values identify the design conditions.



• Loads (F) Applied to Frame by ECU Due to Weight and Humping Loads

$$F_z = (6 + 1)W = 7W$$

$$F_x = W + 10W$$

$$F_y = W + 6W$$

NOTE: Addition is of vector quantities.

• Vertical Shock Caused by ECU

- Take summation of moments about line CG to permit calculation of reactions A_x and B_x , which are equal.

$$\Sigma M_{CG} = 2A_x \times 36 = -7W \times 19$$

$$A_x = \frac{-7 \times 19}{2 \times 36} \times 435$$

$$A_x = B_x = -803.5 = -804 \text{ lb}$$

- Take summation of moments about line AB to permit calculation of the reactions C_x and F_x , which are equal.

$$\Sigma M_{AB} = 2 C_x \times 36 = +7W \times 19$$

$$C_x = F_x = +803.5 = 804 \text{ lb}$$

- This determines the vertical components of the reactions at A, B, C, and G, which are equal.

$$\Sigma F_z = 7W$$

$$A_z = B_z = C_z = G_z = \frac{7W}{4} = \frac{7(435)}{4}$$

NOTE: If shock direction is reversed:

$$A_x = B_x = -\frac{5 \times 19}{2 \times 36}(435) = -574 \text{ lb}$$

$$C_x = G_x = +574$$

$$A_z = B_z = C_z = G_z = \frac{5(435)}{4} = 544 \text{ lb}$$

thus the bolt reactions would be smaller than in the shock direction selected.

• Transverse Shock Caused by ECU

•• Reactions due to deadweight only:

$$\Sigma M_{CG} = 2A_x \times 36 = 19(-W) \quad (A_x = B_x \therefore A_x + B_x = 2A_x)$$

$$A_x = B_x = \frac{19}{2 \times 36} (-435)$$

$$A_x = B_x = -114.8 \text{ lb} = -115 \text{ lb}$$

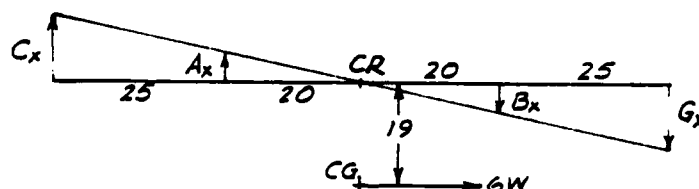
ΣM_{AB} : Using same procedure as above:

$$C_x = G_x = +114.8 \text{ lb} = 115 \text{ lb}$$

•• Reactions due to impact of 6W only:

Assume that the frame is rigid and that bolt forces are proportional to their distance from center of rotation.

Looking down on the shelter and frame permits the relationship between the x-components of the bolt reactions to be determined. By symmetry: $G_x = C_x$ and $B_x = A_x$.



Using similar triangles: $\frac{C_x}{45} = \frac{A_x}{20}$

$A_x = B_x = \frac{20}{45} C_x = \frac{20}{45} G_x$; Neglecting signs, take summation of moments about the center of rotation to enable C_x to be determined.

$$\Sigma M_{CR} = 2 C_x 45 + 2 A_x 20 = 19 \times 6W = 114W$$

Substituting for A_x , and solving for C_x

$$2 C_x 45 + 2\left(\frac{20}{45} C_x\right) 20 = 114W$$

$$C_x = -\frac{114}{107.78} W = -\frac{114}{107.78} (435) = -460.1$$

Use the relationship developed above to determine the other components.

$$C_x = -460 \text{ lb} = -G_x$$

$$A_x = -\frac{20}{45}(460) = -204.5 \text{ lb} = -B_x$$

Take summation of forces in the transverse direction to enable the components of the reactions in that direction to be determined.

$$\Sigma F_y = 6W; A_y = B_y = C_y = G_y = \frac{6W}{4} = \frac{6 \times 435}{4} = 652.5 = 653$$

The summation of forces in the vertical direction allows the z-components of the bolt reactions to be determined.

$$\Sigma F_z = 435; A_z = B_z = C_z = G_z = \frac{W}{4} = \frac{435}{4} = 109 \text{ lb}$$

- The summation of forces in the x-direction is used to establish the bolt reaction components in that direction.

*If shock reversed, change signs

$$\Sigma F_x = 0 \quad A_x = -115 - 205* = -320$$

$$B_x = -115 + 205* = 90$$

$$C_x = 115 - 460* = -345$$

$$G_x = 115 + 460* = +575$$

$$\text{Check } \Sigma F_x = 0 \quad \text{OK}$$

• Longitudinal Shock Caused by ECU

- Reactions due to weight only, see first double bullet under "Transverse Shock" paragraph, above.

$$A_x = B_x = -115$$

$$C_x = F_x = 115$$

- Reactions due to the impact of 10W only:

Take summation of moments about CG to permit calculations of the reactions A_x and B_x .

$$\Sigma M_{CG} = 2 \times A_x \times 36 = 10W \times 13 = 130W$$

$$A_x = B_x = \frac{130}{2 \times 36} W = \frac{130}{2 \times 36} (435) = 785.4 \text{ lb} = 785 \text{ lb}$$

Take summation of moments about a line through A and B to permit calculation of the reactions C_x and F_x , which are equal.

$$\Sigma M_{AB} = 2 \times C_x \times 36 = 10W \times (36 - 13) = 230W$$

$$C_x = \frac{230}{2 \times 36} (435) = 1389.6$$

$$C_x = G_x = 1390$$

Take summation of forces in the longitudinal direction to enable the components of the reactions in that direction to be determined.

$$\Sigma F_x = 10W$$

*If shock direction is reversed, change signs:

$$A_x = -115 + 785* = 670$$

$$A_x = -900$$

$$B_x = -115 + 785* = 670$$

$$B_x = -900$$

$$C_x = +115 + 1390* = 1505$$

$$C_x = -1275$$

$$G_x = +115 + 1390* = 1505$$

$$G_x = -1275$$

$$2 (670 + 1505) = 4350 = 10W \quad \text{OK}$$

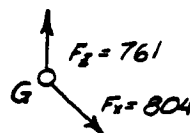
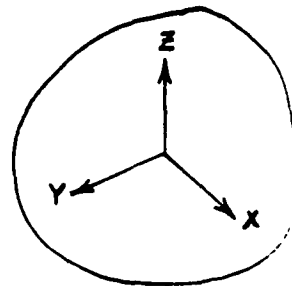
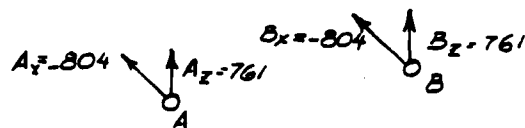
The summation of the forces in the vertical direction allows the four z-components of the bolt reactions to be determined; these are assumed to be equal.

$$\Sigma F_z = 435$$

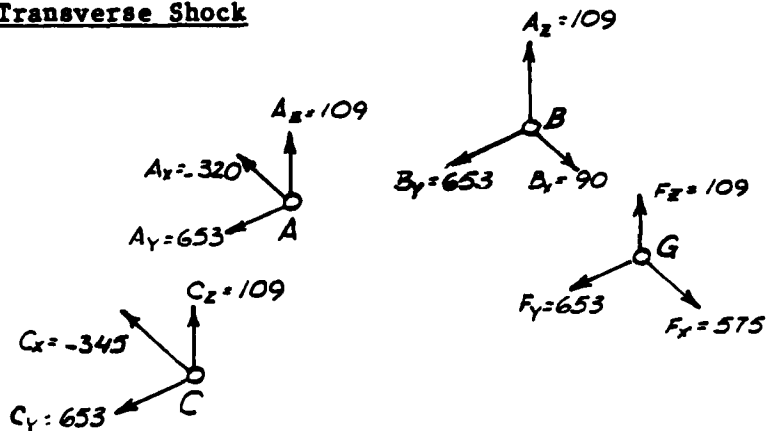
$$A_z = B_z = C_z = F_z = \frac{W}{4} = \frac{435}{4} = 109 \text{ lb}$$

• Summary - Mounting bolt reactions at Points A, B, C, and G for humping loads.

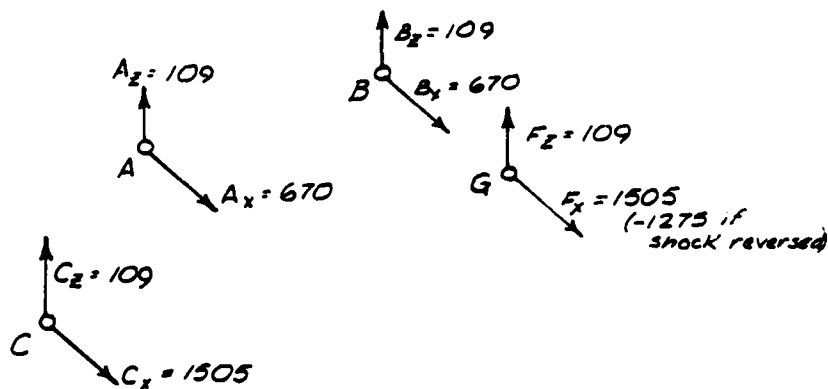
•• Vertical Shock



•• Transverse Shock



•• Longitudinal Shock



• Design Conditions for Connections of Frame to Shelter (abstracted from preceding summary)

Max Shear in Y-Z Plane

Vertical Shock $F_z = 761 \text{ lb}$

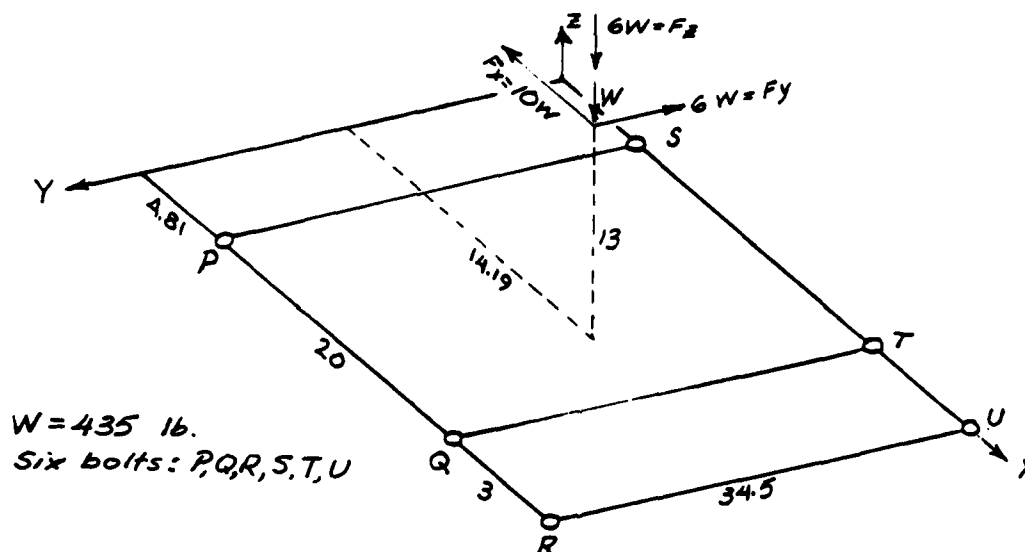
Max Tension

Longitudinal Shock $F_x = -1275 \text{ lb}$

Max Compression

Longitudinal Shock $F_x = 1505 \text{ lb}$

III-2-3 ECU Mounting Bolt Reactions



• Vertical Shock

- Take the summation of moments about the line PS and calculate the Z-components of the bolt reactions.

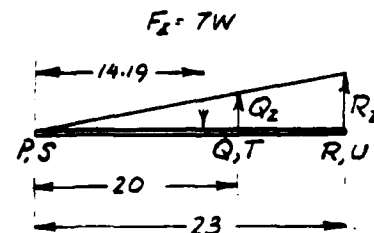
ΣM_{ps}

$$2R_z \cdot 23 + 2Q_z \cdot 20 = 7W (14.19)$$

Assume that the frame and ECU base are rigid. Use similar triangles to establish relationship between Q_z and R_z .

$$\text{but } \frac{Q_z}{20} = \frac{R_z}{23} \therefore Q_z = \frac{20}{23} R_z$$

$$R_z (46 + 40 \times \frac{20}{23}) = (7 \times 14.19)(435)$$



$$R_z = U_z = 534.9 = 535$$

$$Q_z = T_z = \frac{20}{23} (535) = 465.11 = 465$$

- Take the summation of forces in the vertical direction and calculate the two unknown bolt reactions in that direction which are equal, $P_z = S_z$.

$$\Sigma F_z \quad P_z = S_z = \frac{7W - 2(535 + 465)}{2} = [7(435) - 2000] \div 2 = 522.5 = 523$$

$$\text{Check} = 2(523 + 465 + 535) = 3046 = 7W = 7(435) \\ 3046 = 3045$$

- Transverse Shock. Determine the vertical components of the bolt reactions due to the weight of the ECU, W, and to the transverse shock, 6W.

- Due to Weight (divide quantities from "Vertical Shock" paragraph, above, by 7):

$$R_z = U_z = \frac{535}{7} = 76.4 = 76 \text{ lb}$$

$$Q_z = T_z = \frac{465}{7} = 66.4 = 66 \text{ lb}$$

$$P_z = S_z = \frac{523}{7} = 74.7 = 75 \text{ lb}$$

- Due to Transverse Shock, 6W

Take summation of moments about line AC and solve for vertical components of bolt reactions.

$$\Sigma M_{AC}$$

$$D_z = E_z = G_z = \frac{6W \times 13}{(3)34.5} = \frac{6(435) \times 13}{34.5(3)} = 327.8 = 328 \text{ lb}$$

Take summation of vertical forces, note that $A_z = B_z = C_z$

$$P_z = Q_z = R_z = -328 \text{ lb}$$

Due to both weight and transverse shock

$$P_z = -328 + 75 = -253 \text{ lb} \quad S_z = +328 + 75 = 403 \text{ lb}$$

$$Q_z = -328 + 66 = -262 \text{ lb} \quad E_z = +328 + 66 = 394 \text{ lb}$$

$$R_z = -328 + 76 = -252 \text{ lb} \quad U_z = +328 + 76 = 404 \text{ lb}$$

- Determine the transverse components of the bolt reactions due to the transverse shock, 6W, these are assumed as being equal.

$$\Sigma F_y = 6W$$

$$P_y = Q_y = R_y = S_y = T_y = U_y = \frac{6W}{6} = \frac{6(435)}{6} = 435 \text{ lb}$$

- Longitudinal Shock. Determine the vertical components of the bolt reactions due to the weight of the ECU, W, and to the longitudinal shock, 10W.

- Due to Weight, W (Same as above)

$$R_z = U_z = 76 \text{ lb}$$

$$Q_z = T_z = 66 \text{ lb}$$

$$P_z = S_z = 75 \text{ lb}$$

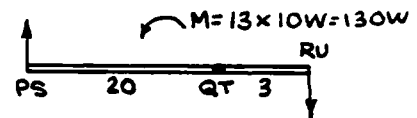
- Due to Transverse Shock, 10W

Take the summation of moments about line QT and determine the vertical components of the bolt reactions at P, S and R, U.

$$\Sigma M_{BF} = 0$$

$$2 \times 20 \times P_z + 2 \times 3 \times R_z = M = 130 \times W$$

$$\text{But } \frac{P_z}{20} = \frac{R_z}{3} \therefore R_z = \frac{3}{20} P_z, \text{ because frame is rigid}$$



$$P_z (40 + 6 \frac{3}{20}) = 130 \times 435$$

$$P_z = \frac{130 \times 435}{40.9} = 1383 \text{ lb} = S_z$$

$$R_z = \frac{3}{20} \times 1383 = -207 \text{ lb} = U_z \quad \text{Negative sign used to indicate tension.}$$

- Take the summation of forces in the vertical direction to determine the vertical components of the reactions Q and S.

$$\Sigma F_z = 0 \text{ (Due to moment only)}$$

$$P_z + Q_z + R_z = 0$$

$$T_z = Q_z = -(P_z + R_z) = -(1383 - 207) = -1176 \text{ lb}$$

- Summary of forces in z-direction due to both weight and longitudinal shock.

$$P_z = 75 + 1383 = 1458 \quad S_z = 75 + 1383 = 1458$$

$$Q_z = 66 - 1176 = -1110 \quad T_z = 66 - 1176 = -1110$$

$$R_z = 76 - 207 = -131 \quad U_z = 76 - 207 = -131$$

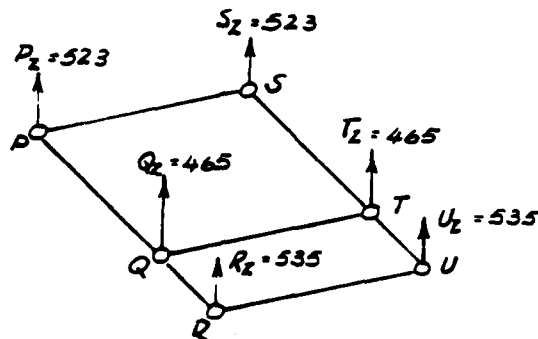
- Determine the longitudinal components of the bolt reactions due to the longitudinal shock of 10W. These reactions are equal.

$$\Sigma F_x = 10W$$

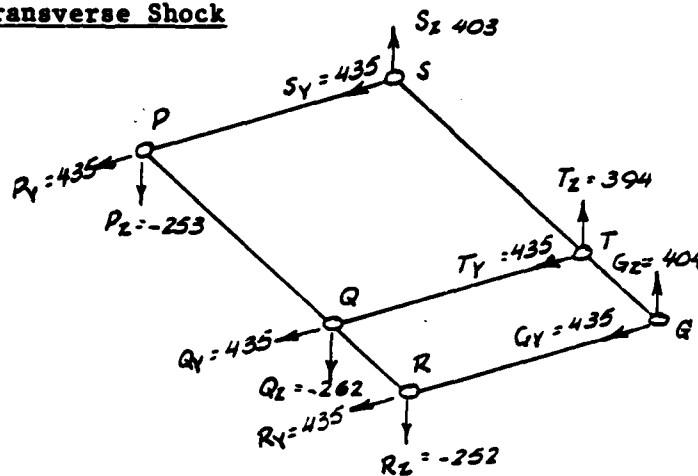
$$P_x = Q_x = R_x = S_x = T_x = U_x = \frac{10W}{6} = \frac{10 \times 435}{6} = 725 \text{ lb}$$

● Summary - ECU Mounting Bolt Reactions

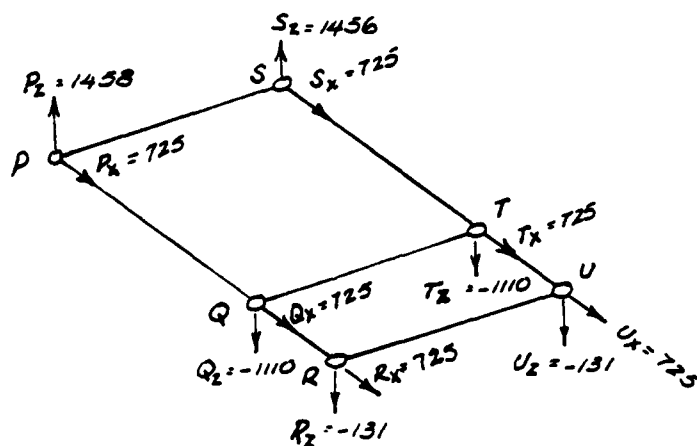
●● Vertical Shock



●● Transverse Shock



●● Longitudinal Shock



III-2-4. Forces and Moments Acting on Members of Frame, (see paragraph III-2-2 for sketch).

• Member DH (and EJ), Base Beams

- Vertical Shock. (Forces from previous subparagraph "Summary - ECU Mounting Bolt Reactions.")

$$\Sigma M_D: H_z = \frac{(523 \times 4.81) + (465 \times 24.81) + (535 \times 27.81)}{36}$$

$$H_z = 803.6 = 804 \text{ lb}$$

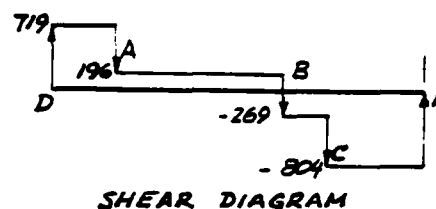
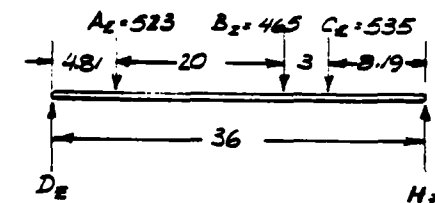
$$\Sigma F_z: D_z = 523 + 465 + 535 - 804$$

$$D_z = 719 \text{ lb}$$

Since shear goes through zero at point B, the bending moment will be a maximum there, in vertical plane.

$$M_B = 719 \times 24.81 - 523 \times 20$$

$$M_B = 7378 \text{ in lb}$$



- Transverse Shock, Forces from paragraph: "Summary - ECU Mounting Bolt Reactions", above.

Vertical Forces

$$\Sigma M_D: H_z = \frac{(403 \times 4.81) + (394 \times 24.81) + 404(27.81)}{36}$$

$$H_z = 637 \text{ lb}$$

$$\Sigma F_z: D_z = 403 + 394 + 404 - 637 = 564 \text{ lb}$$

Since shear goes through zero at point B, max moment is there.

Moment at B in vertical plane = M_{B-v}

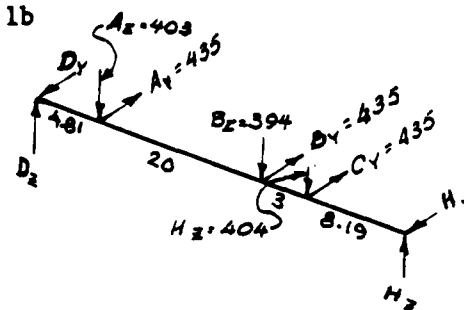
$$M_{B-v} = 564 \times 24.81 - 403 \times 20$$

$$M_{B-v} = 5933 \text{ in lb}$$

Horizontal Forces

$$\Sigma M_D: H_y = \frac{435(4.81 + 24.81 + 27.81)}{36} = 694 \text{ lb}$$

$$\Sigma F_y: D_y = 3 \times 435 - 694 = 611 \text{ lb}$$



Max Mom Horiz is at point B (M_{B-H});
shear goes through zero.

$$M_{B-H} = 611 \times 24.81 - 435 \times 20$$

$$M_{B-H} = 6459 \text{ in lb}$$

So, beam must withstand moments in:

Vertical plane, $M_{B-V} = 5933 \text{ in lb}$

Horizontal plane, $M_{B-H} = 6459 \text{ in lb}$

●● Longitudinal Shock, Forces from paragraph: "Summary - ECU Mounting Bolt Reactions."

$$\Sigma M_D: H_z = \frac{(-1458 \times 4.81 + 1110 \times 24.81 + 131 \times 27.81)}{36}$$

$$H_z = -671 \text{ lb}$$

$$\Sigma F_z: D_z = 1458 - 1110 - 131 + 671$$

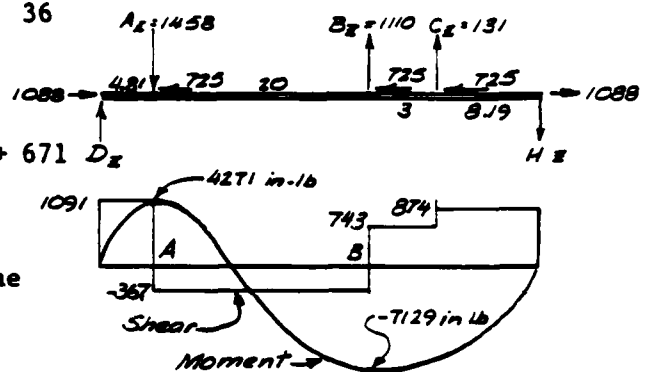
$$D_z = 888 \text{ lb}$$

Moments in vertical plane

$$M_A = 888 \times 4.81 = 4271$$

$$M_B = 888(24.81) - 1458 \times 20 = -7129 \text{ lb Max}$$

(top of beam in tension)



●● Allowable Stresses

Allow stress = Min Stress + Factor of Safety of 2.5
Material: Alum Alloy Extrusion 6061-T6

		Strength Min psi	Allow Stress (S_a) psi
Tension	Ultimate	38,000	15,200
	Yield	35,000	14,000
Shear	Ultimate	24,000	9,600
	Yield	20,000	8,000
Compression	Yield	35,000	14,000

•• Member DH - Select Structural Shape

Requirements

Bending Moment, Vertical Plane, $M_v = 7378$ in lb (from above)

Bending Moment, Horizontal Plane, $M_H = 6459$ in lb (from above)

Section Modulus

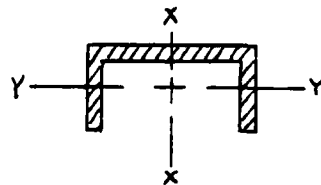
$$\text{Vertical Plane} = M_v \div S_a = 7378 \text{ in lb} \div 14000 \frac{\text{lb}}{\text{in}^2} = 0.527 \text{ in}^3$$

$$\text{Horizontal Plane} = M_H \div S_a = 6459 \div 14000 = 0.461 \text{ in}^3$$

Selection: AA STD Channel 4.0 D x 2.25 W x 2.331 lb/ft.

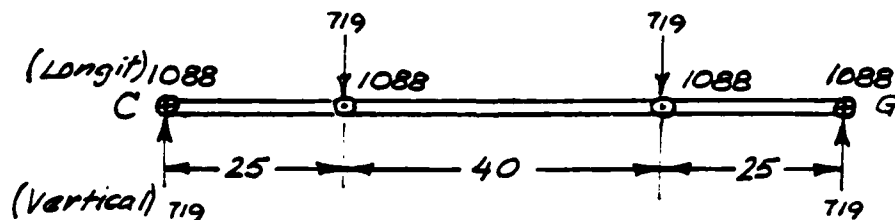
$$S_{xx} = 2.60 \text{ in}^3 \text{ (Horizontal) OK, } > 0.461$$

$$S_{yy} = 0.69 \text{ in}^3 \text{ (Vertical) OK, } > .527$$



• Member GF

This member would be subjected to bending moments in the vertical plane due to the effects of vertical shock, which is represented by the two 719 lb forces, applied at points D and E. These forces are developed earlier in paragraph III-2-4. The effect of longitudinal shock would be to apply two loads of 1088 pounds each in the horizontal direction of points D and E. These forces can be developed by dividing the sum of the three horizontal forces, 725 lb each shown in the sketch of paragraph III-2-4 •, third ••, by two. While the structure supporting the ECU could be analyzed as a truss in the horizontal plane, it was felt that it should be designed as though the structural elements CG acted as a beam in the horizontal plane as it does in the vertical plane. This would maintain structure strength in the horizontal plane even though the comparatively light diagonal members CH and FJ might be damaged.



Maximum Moments

In vertical plane $M_v = 719 \times 25 = 17,975 \text{ in lb}$

In horizontal plane $M_H = 1088 \times 25 = 27,200 \text{ in lb}$

Section Modulus, Req'd (For Factor of Safety of 2.5 based on yield)

In vertical plane $S_v = \frac{M_v}{S_{ac}} = \frac{17975}{14000} = 1.28 \text{ in}^3$

In horizontal plane $S_H = \frac{M_H}{S_{ac}} = \frac{27200}{14000} = 1.94 \text{ in}^3$

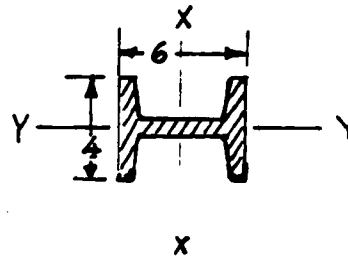
Selection

Alum Assoc Std I-Beam

6D x 4W x 4.03 lb/ft

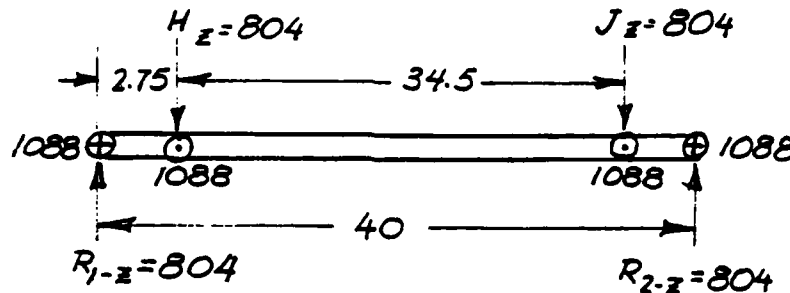
$S_{yy} = S_v = 1.55 \text{ in}^3 \text{ OK, } > 1.28$

$S_{xx} = S_H = 7.33 \text{ in}^3 \text{ OK, } > 1.94$



• Member HJ

The two forces acting in the vertical plane (804 lb) and the two separately in the horizontal plane (1088 lb) were developed earlier in this numbered paragraph.



Maximum Moments

In vertical plane

$M_v = 804 \times 2.75 = 2211 \text{ in lb}$

In horizontal plane

$M_H = 1088 \times 2.75 = 2992 \text{ in lb}$

Section Modulus, Req'd

In vertical plane $S_v = \frac{M_v}{S_{ac}} = \frac{2211}{14000} = 0.16$

In horizontal plane $S_H = \frac{M_H}{S_{ac}} = \frac{2992}{14000} = 0.214$

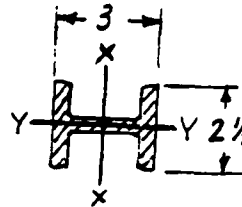
Selection

Alum Assoc Std I-Beam

3D x 2-1/2W x 1.637 lb/ft

$S_v = S_{yy} = 0.42 > 0.16$ OK

$S_H = S_{xx} = 1.49 > 0.214$ OK

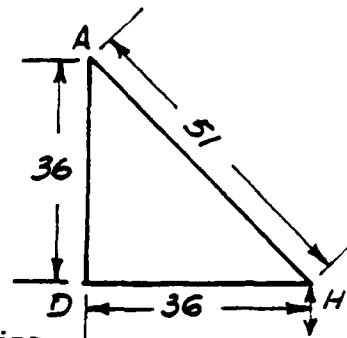


• Member AH (and BJ)

Force in AH can be either tension or compression. Use compression for design purposes.

$$AH = \sqrt{2} \times 804 = 1137 \text{ lb}$$

For column in compression see Reference 2, page 48 for 6061-T6, buckling formula constants: B = 39.9, D = 0.263, C = 68



Trial Selection

2 inches OD x 1/4 inches wall round tubing

$$\text{Metal area} = \frac{\pi}{4} (2^2 - 1.5^2) = 1.3744 \text{ in}^2$$

Radius of gyration, $r = 0.625$

$$\therefore \frac{1}{r} = \frac{51}{.625} = 81.6$$

Ultimate strength, since $\frac{1}{r} > 68$

$$f_c = \frac{102000}{(\frac{1}{r})^2} = \frac{102000}{(81.5)^2} = 15.32 \frac{\text{Kips}}{\text{in}^2} = 15,320 \text{ psi}$$

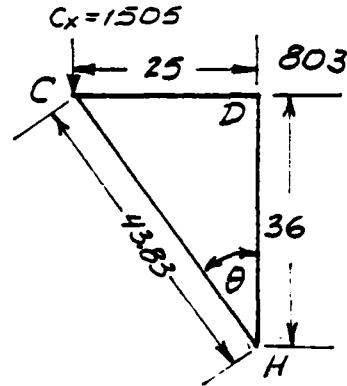
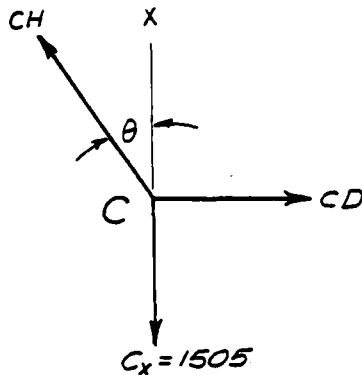
$$F_c = 1.3744 \text{ in}^2 \times 15,320 \frac{\text{lb}}{\text{in}^2} = 21,054 \text{ lb}$$

Factor of Safety FS

$$FS = \frac{21,054}{1137} = 18.5 \text{ OK since } FS > 2.5$$

• Member CH

The maximum compressive load in this member can be calculated using the maximum value of the reaction at mounting bolt "C" as summarized near the end of paragraph III-2-2. This is a load of 1505 lb. in the longitudinal direction, caused by the shock of 10 g's in that direction.



Take summation of forces in the x-direction at the bolt joint "C" to allow calculation of the maximum compressive load in members CH.

$$CH \cos \theta = C_x$$

$$CH = \frac{C_x}{\cos \theta} = \frac{1505 \text{ lb}}{36/43.83} = 1505 \text{ lb} \left(\frac{43.83}{36} \right) = 1832 \text{ lb}$$

Trial Selection of Structural Element

2 inches OD x 1/4 inch wall round tubing

Metal cross-sectional area = $A_m = 1.3744 \text{ in}^2$

radius of gyration = $r = 0.625 \text{ in.}$

$$\frac{l}{r} = \frac{43.83 \text{ in}}{0.625 \text{ in}} = 70.128$$

since $\frac{l}{r} > 68$, determine allowable compressive stress f_c using:

$$f_c = \frac{102,000}{\left(\frac{l}{r} \right)^2} = \frac{102,000}{(70.128)^2} = 20.74 \frac{\text{kips}}{\text{in}^2} = 20,740 \text{ psi}$$

Allowable compressive load, F_c

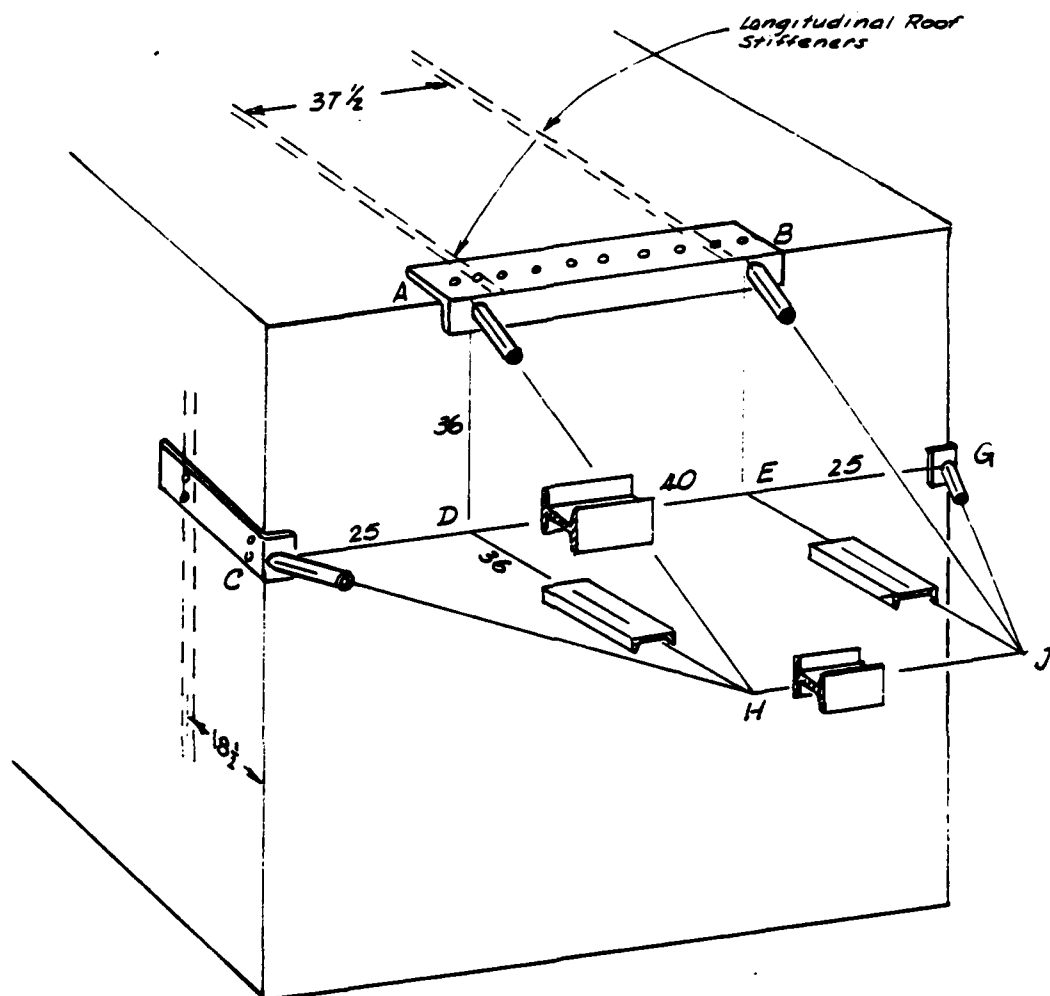
$$F_c = f_c \times A_m = 20.740 \frac{\text{lb}}{\text{in}^2} \times 1.3744 \text{ in}^2 = 28,506 \text{ lb}$$

Factor of Safety, FS

$$FS = \frac{F_c}{CG} = \frac{28,506 \text{ lb}}{1832 \text{ lb}} = 15.56$$

OK Since $FS > 2.5$

• General Arrangement



MEMBER

AB	Aluminum Association Standard Angle, 6D x 6W x 1/2 x 6.75 lb/ft
CG	Aluminum Association Standard I-Beam, 6D x 4W x 4.03 lb/ft
DH,EJ	Aluminum Association Standard Channel, 4D x 2.25W x 2,331 lb/ft
HJ	Aluminum Association Standard I-Beam, 3D x 2-1/2W x 1.637 lb/ft
AH,CH,BJ,GJ	Round Tube, 2 in OD x 1/4 in Wall x 1.62 lb/ft
C,G	Rectangular bar, 4W x 1/4

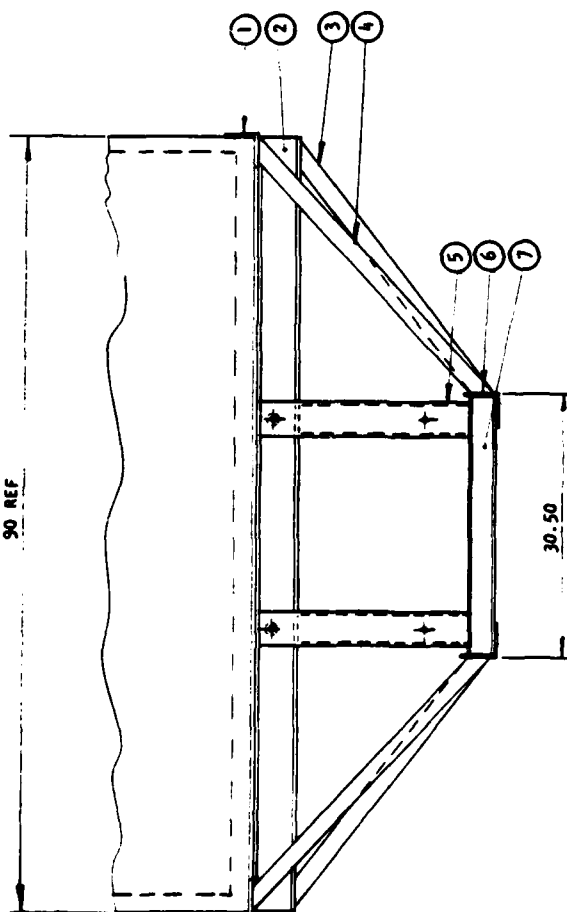
NOTE: Material: Aluminum Alloy 6061-T6

APPENDIX III-3. WALL MOUNTING DESIGNS

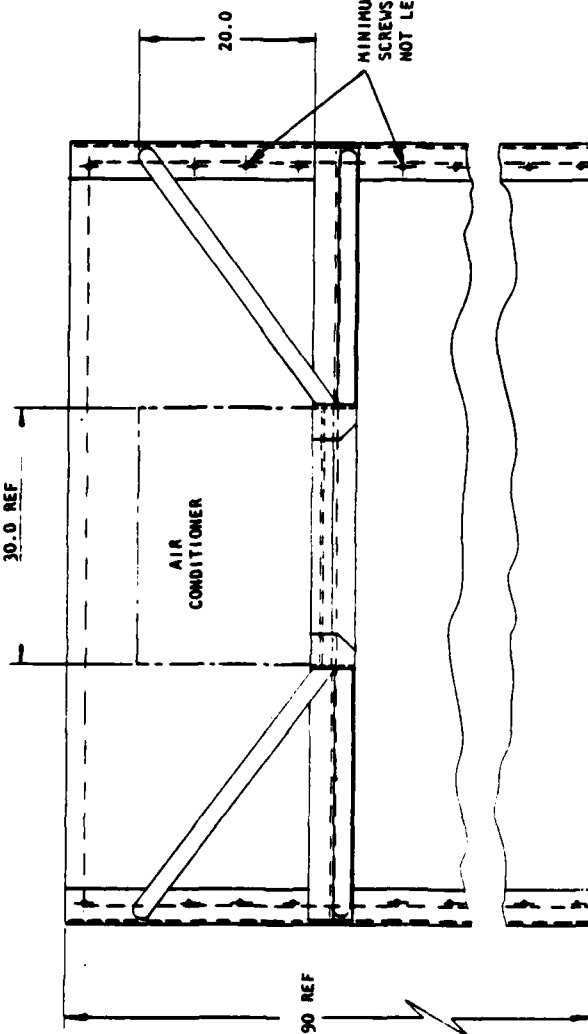
Contents

- Figure III-3-1: Mounting design for single 18,000 Btuh horizontal ECU (adaptable for 9,000 Btuh horizontal ECU).
- Figure III-3-2: Mounting design for two 18,000 Btuh horizontal ECU's (adaptable for two 9,000 Btuh horizontal ECU's or one 18,000 Btuh horizontal ECU and one GPFU).
- Figure III-3-3: Mounting for single 36,000 Btuh horizontal ECU.

90 REF



30.0 REF



III-3-2

NOTES:

1. ALL STRUCTURAL ELEMENTS ARE ALUMINUM ALLOY 6061-T6.
2. ALL DIMENSIONS ARE IN INCHES.

FIND NO.	QTY	DESCRIPTION
1	2	Angle, 5 x 5 x 3/8 x 4.23 lb/ft
2	1	Wide Flange, Army-Navy, 5 x 5, 5.366 lb/ft
3	2	Tube, 2.00 x 1/2 Wall
4	2	Tube, 2.00 x 1/2 Wall
5	2	Channel, Alum. Assoc., 4 x 2, 1.738 lb/ft
6	2	Angle, 4 x 4 x 1/2, 2.28 lb/ft
7	1	I-Beam, Alum. Assoc., 3 x 2.50, 1.637 lb/ft

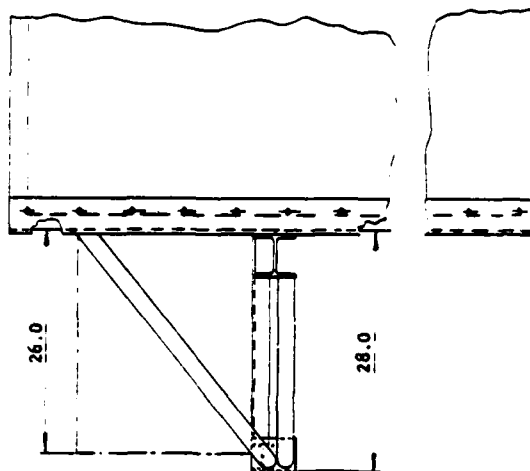
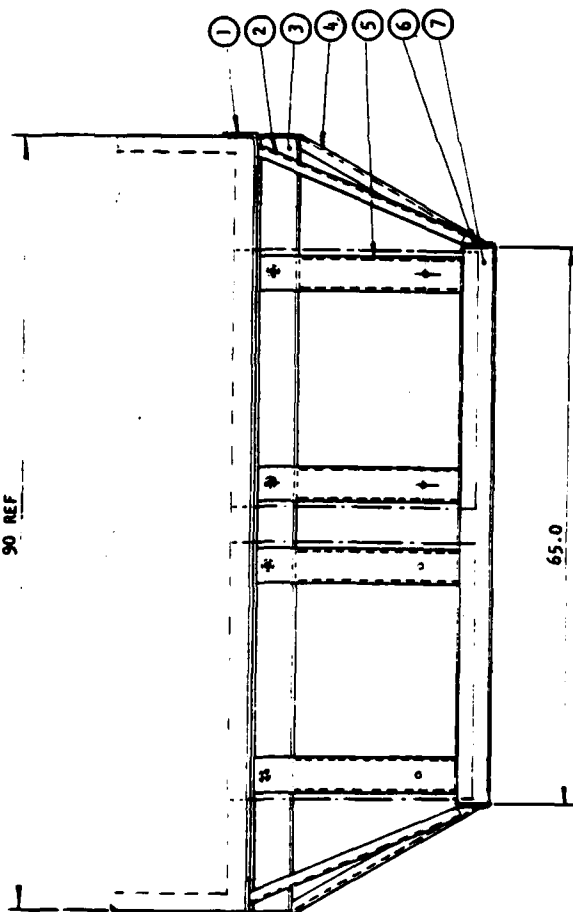
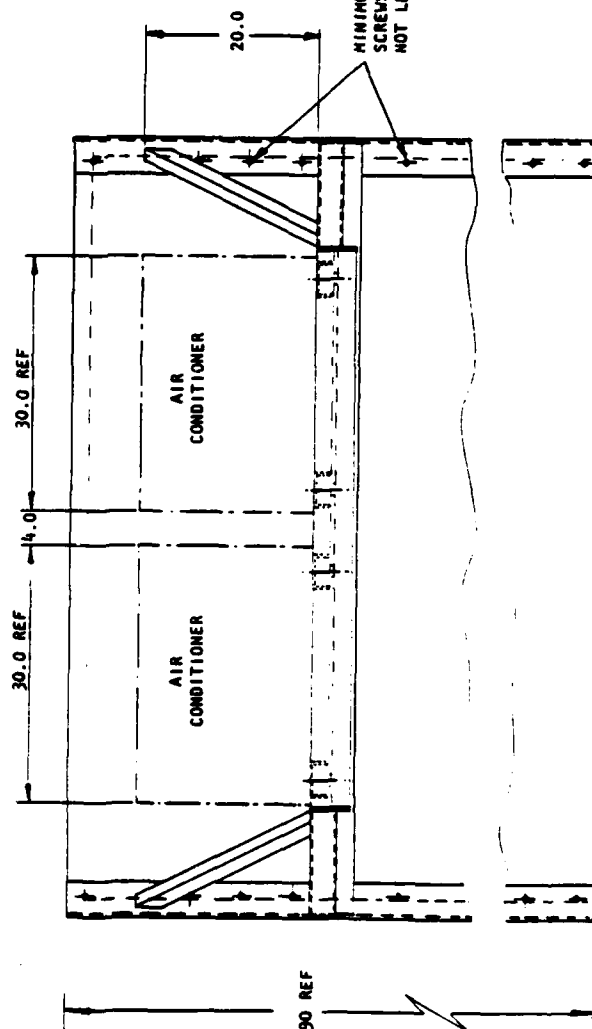


Figure III-3-1. MOUNTING FOR ONE 18,000 BTUH ECU
ON S280 TACTICAL SHELTER

90 REF



III-3-3



NOTES:

1. ALL STRUCTURAL ELEMENTS ARE ALUMINUM ALLOY 6061-T6.
2. ALL DIMENSIONS ARE IN INCHES.

FIND NO.	QTY	DESCRIPTION
1	2	Angle, 5 x 5 x 3/8 x 4, 28 lb/ft
2	2	Channel, Army-Navy, 3 x 1.375, 0.993 lb/ft
3	1	Wide Flange, Army-Navy, 5 x 5, 5.366 lb/ft
4	2	Channel, 4 x 4 x 1/2, 2.28 lb/ft
5	4	Channel, Alum. Assoc., 4 x 2, 1.738 lb/ft
6	2	Plate, 3/8 Thk, 6061-T651
7	1	Wide Flange, Army-Navy, 4 x 4 1/2, 2.867 lb/ft

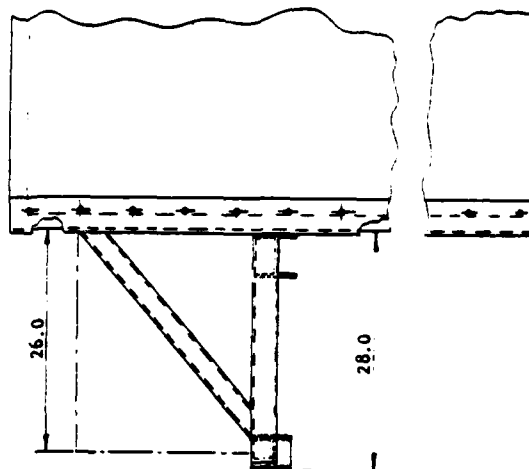
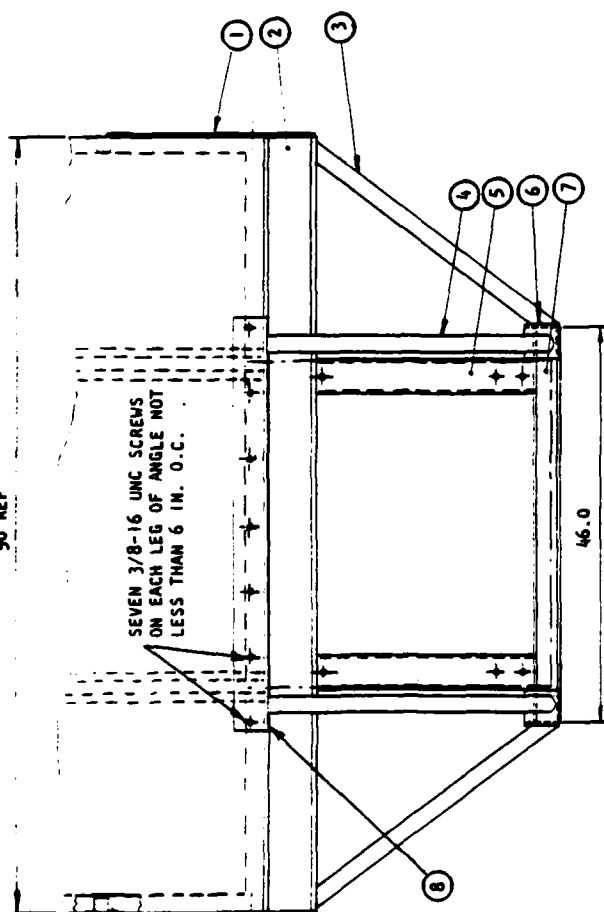


Figure III-3-2. MOUNTING FOR TWO 18,000 BTUH ECU ON S280 TACTICAL SHELTER

90 REF

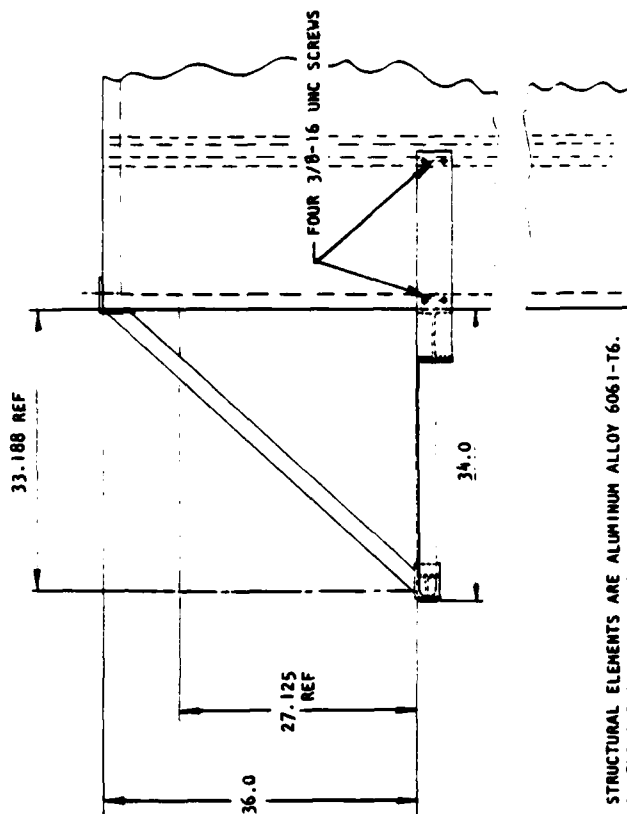


FIND NO.	QTY	DESCRIPTION
1	2	Rect. Bar, 4 x 4
2	1	I-Beam, Alum. Assoc., 6 x 4, 4.03 lb/ft
3	2	Tube, 2 OD x 1/2 Wall
4	2	Tube, 2 OD x 1/2 Wall
5	2	Channel, Alum. Assoc., 4 x 2.25, 2.331 lb/ft
6	2	Angle, 4 x 3 x 1/2
7	1	I-Beam, Alum. Assoc., 3 x 2.5, 1.637 lb/ft
8	1	Angle, 6 x 6 x 1/2 x 6.75 lb/ft

TO DEVELOP 4 PSI NUCLEAR OVERPRESSURE RESISTANCE WHEN MOUNTED ON HARDENED SHELTER, SUBSTITUTE:

FIND NO.	QTY	DESCRIPTION
2	1	I-Beam, A-N, 5 x 5 x 5.366 lb/ft
5	2	Channel, Alum. Assoc., 5 x 2.75 x 3.089 lb/ft

III-3-4



NOTES:

1. ALL STRUCTURAL ELEMENTS ARE ALUMINUM ALLOY 6061-T6.
2. ALL DIMENSIONS ARE IN INCHES.

Figure III-3-3. MOUNTING FOR ONE 36,000 BTUH ECU ON S380 TACTICAL SHELTER

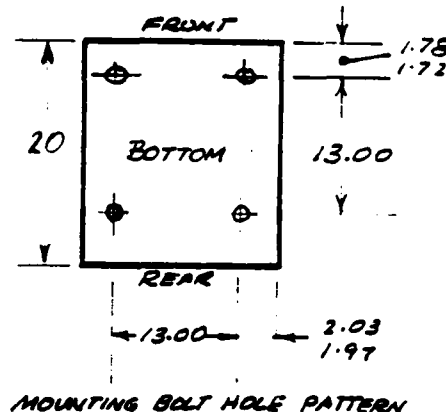
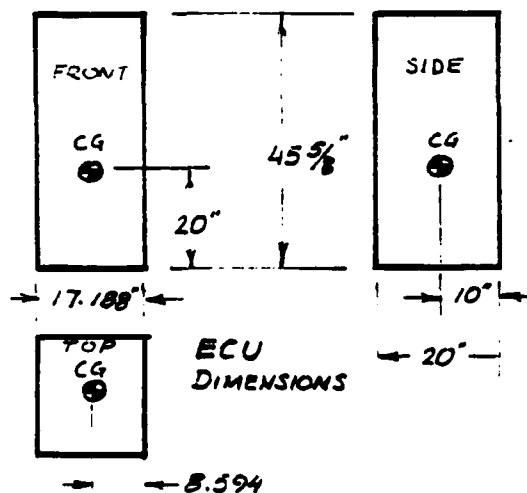
APPENDIX III-4. SAMPLE CALCULATIONS: REMOTE GROUND
FOR 18,000 BTUH VERTICAL ECU

1. Description of Problem

Design a simple aluminum mounting for an 18,000 Btuh ECU which will be remote from the shelter and rest on the ground. The mounting must be strong enough to support the ECU during rail movement¹ and withstand nuclear overpressure up to 7.3 psi. The mounting should be adaptable to other, smaller ECU's by adjusting the lengths of structural members.

2. Key Data for ECU

- Weight: 260 pounds
- Design load: $10 \times 260 = 2600$ pounds
- Dimensions: See Sketch

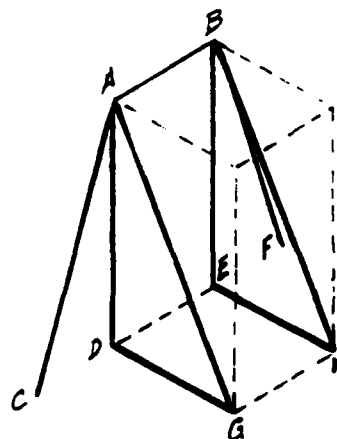


3. Concept

- See Sketch

- Dimensions:

AB = DE = GH	= 18.5 in.
CD = EF	= 22.25 in.
AD = BE	= 45.625 in.
DG = EH	= 26 in.



¹Dynamic loadings caused by acceleration due to rail humping are 6g in transverse and vertical directions and 10g in the longitudinal direction.

$$AG = BH = \frac{45.625}{\sin \theta} = 52.44 \text{ in.}$$

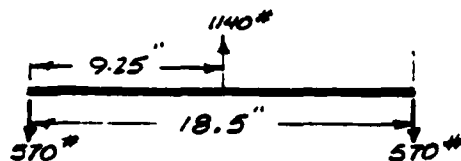
$$AC = BF = 50.76 \text{ in.}$$

4. Member A-B

- $R_1 \times 45.625 = 2600 \times 20$

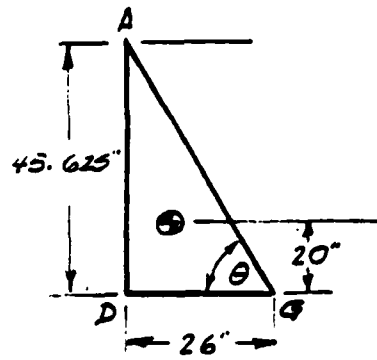
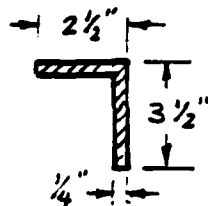
$$R_1 = 1140 \text{ lb.}$$

- Maximum bending moment



$$M_{\text{Max}} = 570 \times 9.25 = 5273 \text{ lb in}$$

- Try: Aluminum 6061-T6 angle ($F_{cy} = 35,000 \text{ psi}$).



Section Modulus = $S = 0.38 \text{ in}^3$
 (NOTE: All section data and allowable loads used in these computations are from Reference 1.)

$$f_b = \frac{M}{S} = \frac{5273 \text{ lb. in.}}{.38 \text{ in}^3} = 13,876 \text{ psi}$$

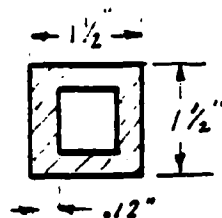
$$M.S = \frac{F_{cy}}{f_b} = \frac{35,000}{13,876} = 2.52, \text{ OK}$$

5. Members AG and BH

- Compression load

$$f_{\text{comp}} = \frac{570}{\cos \theta} = \frac{570}{.494} = 1178 \text{ lb}$$

- Try: Aluminum 6063-T52, 1-1/2-in. square tubing



$$\text{Area} = 0.663 \text{ in}^2, r = 0.565, F_{cy} = 21,000 \text{ psi}$$

$$\text{Length} = 52.44 \text{ in}$$

$$L/r = \frac{52.44}{0.565} = 92.8$$

- Member is critical in buckling

$$\text{Allowable } f_{\text{comp}} = 21,000 - \frac{245}{C} \times \frac{L}{r} \quad (C = 1.5)$$

$$= 21,000 - \frac{245}{1.5} \times 92.8 = 2440 \text{ psi}$$

Actual compressive stress

$$F_{\text{comp}} = \frac{1178}{.663} = 1777 \text{ psi}$$

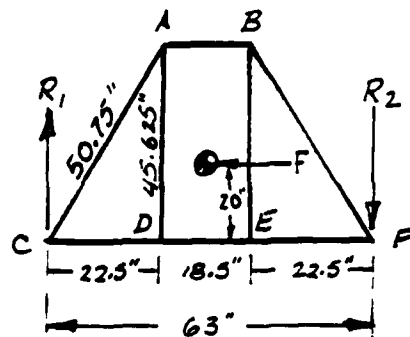
$$\text{M.S.} = \frac{2440}{1777} = 1.37 \text{ OK}$$

6. Members AC and BF

$$R_1 = R_2 = \frac{2600 \times 20}{63} = 825 \text{ lb.}$$

$$F_{FB} = \frac{50.75}{45.625} \times 825 = 918 \text{ lb.}$$

Members AC and BF are same aluminum sections as AG and BH but design loads are lower by the ratio of $\frac{918}{1178}$. Therefore, AC and BF are OK.

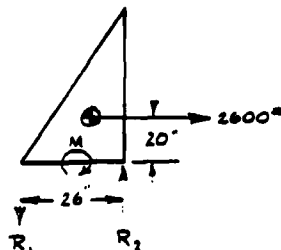


7. Members DG and EH

- Assume worst case: total moment load carried by DG and EH; ECU not connected to AB.

$$M = 2600 \times 20 = 52,000 \text{ lb-in}$$

$$R_1 = R_2 = \frac{52000}{26} = 2000 \text{ lb}$$

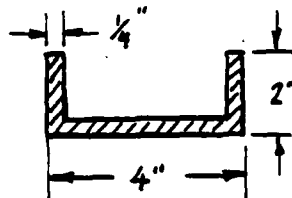


- Maximum bending moment per member:

Load will be divided equally between DG and EH.

$$M_{\max} = \frac{R}{2} \times \frac{26}{2} = \frac{2000 \times 26}{2 \times 2} = 13,000 \text{ lb-ft}$$

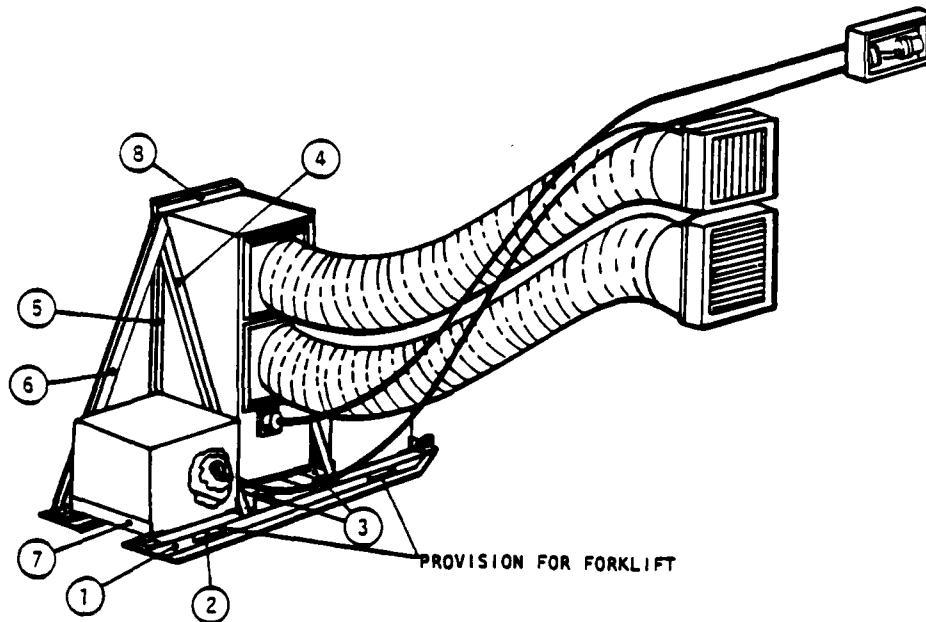
Try: Aluminum 6061-T6 Channel, $S = 0.452$, $F_{cy} = 35000 \text{ psi}$



$$f_b = \frac{M}{S} = \frac{13000}{.452} = 28,760 \text{ psi}$$

$$M.S. = \frac{35,000}{28,760} = 1.22, \text{ OK}$$

APPENDIX III-5. REMOTE GROUND MOUNTING DESIGN



FIND NO.	QTY	DESCRIPTION	NOMINAL LENGTHS		
			6000 BTUH VERTICAL ECU	9000 BTUH VERTICAL ECU	18000 BTUH VERTICAL ECU
1	2	Wide Flange Beam Army-Navy Series 4" x 3" - 1.788 Lbs/Ft	74-1/2"	74-1/2"	74-1/2"
2	2	Channel, Form From 1/8" Thick Sheet	27-3/8"	27-3/8"	27-3/8"
3	2	Channel - Army-Navy 4" x 2" - 2.205 Lbs/Ft	30"	30"	30"
4	2	Tubing, Square, 1-1/2" x 1/8" Thick	40-3/4"	43-5/8"	55"
5	2	Tubing, Square, 1-1/2" x 1/8" Thick	30-1/2"	34-1/4"	47-7/8"
6	2	Tubing, Square, 1-1/2" x 1/8" Thick	37-15/16"	41"	53"
7	4	Angle, 3" x 2" x 1/4"	30"	30"	30"
8	1	Angle, 3-1/2" x 2-1/2" x 1/4"	21"	21"	21"

Material: Find Numbers 1, 2, 3, 7, 8 Aluminum 6061-T6.
Find Numbers 9, 5, 6 Aluminum 6063-T52.

Figure III-5-1. GROUND MOUNT FOR VERTICAL ECU

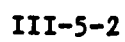


Figure III-5-2. GROUND MOUNT FOR 6,000 BTUH, 9,000 BTUH, AND 18,000 BTUH ECU

APPENDIX VI-1. EMP SHIELDING CONSULTANTS AND MANUFACTURERS

VI-1-1. Introduction

• This appendix contains two lists, both consisting of firms selected at random and generally representative of the types of services and products available. These are not comprehensive lists of firms doing business in this field.

• The first list, in paragraph VI-1-2, contains firms offering consulting services. The second list, in paragraph VI-1-3, contains firms which manufacture products which may be useful in protecting against EMP.

VI-1-2. Design and Engineering Services

- Atlantic Research Corporation
5390 Cherokee Avenue
Alexandria, Virginia 22312
(703) 642-4000
- Elite Electronic Engineering Company
1516 Centre Circle
Downers Grove, Illinois 60515
(312) 495-9770
- IRT Corporation
P.O. Box 80817
San Diego, California 92138
(714) 565-7171
- Mission Research Corporation
1720 Randolph Road
Albuquerque, New Mexico 87106
(505) 843-7200
- R&B Enterprises
P.O. Box 510
Plymouth Meeting, Pennsylvania 19462
(215) 828-6236
- TRW Defense and Space Systems Group
One Space Park
Redondo Beach, California 90278
(213) 535-0126

VI-1-3. Shielding and Protection Materials Manufacturers

- All-tronics, Inc. Power Line Filters
45 Bond Street
Westbury, New York 11590
(516) 333-3090

- Breeze-Illinois, Incorporated
Main Street at Agard Street
Wyoming, Illinois 61491
(309) 695-2511

Cable Shielding
- Chomerics, Inc.
77 Dragon Court
Woburn, Massachusetts 01801
(617) 935-4850
- Enclosure Corporation
4529 Adams Circle
Cornwells Heights, Pennsylvania 19020
(215) 638-9550

Shielded Cabinets
- Flexible Metal Hose Mfg Co
777 W. 16 Street
Costa Mesa, California 92627
(714) 631-3030

Cable Shielding
- General Semiconductor Industries, Inc.
P.O. Box 3078
Tempe, Arizona 85281
(602) 968-3101

EMP Suppressors
- Hopkins Engineering Co.
12900 Foothill Boulevard
San Fernando, California 91342
(213) 361-8691

EM Filters
- Instrument Specialties Company
P.O. Box A
Delaware Water Gap, Pennsylvania 18327
(717) 424-8510

"Finger" Contact Strips
- ITT Cannon Electric
2801 Air Lane
Phoenix, Arizona 85034
(602) 275-4792

Electronic Filters
- METEX Electronic Shielding Group
970 New Durham Road
Edison, New Jersey 08817
(201) 287-0800

Gasketing and Shielding;
Engineering and Design
Service
- Spectrum Control, Inc.
8061 Avonia Road
Fairview, Pennsylvania 16415
(814) 474-1571

Gasketing, Shielding,
Electronic Filters, Air
Vent Shields
- Sprague Electric Company
87 Marshal Street
North Adams, Massachusetts 01247
(413) 664-4411

Electronic Filters;
Consulting Services

- Tecknit, Eastern Division
129 Dermody Street
Cranford, New Jersey 07016
(201) 272-5500

Gaskets, Gasket Material,
Conduction Paints and
Adhesives, Shielded
Windows, Air Vent
Shields, Conductive
Caulking

- Versitron, Inc.
6310 Chillum Place, N.W.
Washington, D.C. 20011
(408) 244-7370

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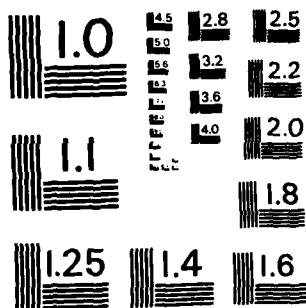
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SUPPLEMENTARY

INFORMATION



DEPARTMENT OF THE ARMY
US ARMY BELVOIR RESEARCH & DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA 22060

STRBE-EME

18 JAN 1984

SUBJECT: AD Number A128632, Title: Integration Engineering Handbook
for Environmental Control

DTIC
Cameron Station
Alexandria, VA 22314

1. Request that enclosed (two page) Errata Sheets (Encl 1) be attached to and made a part of the subject document and included with all future distribution.
2. Point of contact for additional information is Mr. Franklyn P. Good, AV 354-6031 or Comm (703) 664-6031.

FOR THE COMMANDER

1 Encl
as


RICHARD T. SALE
Chief, Engineer
Service Support Laboratory

AD Number A128632

Integration Engineering Handbook for Environmental Control

Errata Sheets (Page 1 of 2)

- Page I-3. Footnote 1, line 3. Change "...six single basic units..." to "...five single basic units...". Change "...two to each side." to "...one or two to each side."
- Page I-4 Figure I-2, Vertical and Sleeve Mounted Configuration (Navy) power consumption 50/60 Hz. Change 10.6 and 16.0 to 2.9 (5) and 5.0 (6), respectively. Add footnotes (5) 2.9 is cooling power. Heating power varies from 2.6 to 10.6. (6) 5.0 is cooling power. Heating power varies from 4.0 to 16.
- Page III-5 Last paragraph, first sentence. Change "...is no gain..." to "...may be a gain..." Last paragraph, second sentence. Change to "The area vacated by the ECU when it is extended may be used for fold out tables or benches to perform administrative and/or technical work."
- Page III-6 Paragraph 4. Delete sentence "The Base Civil Engineer should..."
- Page III-8 Paragraph 6. Second sentence. Change "Addequate" to "Adequate".
- Page III-9 Third double dot paragraph. Add "Mounting method "B" shown in Figure III-4 is better suited for CB and EMI protection".
- Page III-18 Figure III-9a, column "EXTERIOR FIXED WALL MOUNTINGS", row "What ECU sizes can be mounted?" change "GPFU" to "GPFU(1)" Add footnote "(1)See Figure I-1-2, page I-1-3".
- Page V-I Section V-2, first paragraph. Replace second, third, and fourth sentences by "However, for our purposes here, discussion of the threat will be restricted to the effects of CB agents on ECRs and other equipment".
- Page V-4 Last paragraph. Replace middle sentence with "This compartment permits entry of essentially clean personnel into a shelter. The compartment's air wash provides only a limited decontamination capability".
- Page VI-1 Section VI-2, first paragraph. Replace "...60dB over the range... to 1 MHz". with "...at least 60 dB over the frequency range from approximately .15 MHz to 450 MHz".

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Integration Engineering Handbook for Environmental Control

Errata Sheets (Page 2 of 2)

- Page VI-2 Section VI-4, second paragraph. Replace "DOD" with
"appropriate military" Add in footnote 1,

Department of the Air Force Department of the Navy
San Antonio Air Logistics Center HQ US Marine Corps
SA-ALC/PMDM ATTN: LME
Kelly AFB TX 78241 Washington DC 20380

AV 945 7762 AV 227 3664
- Page VI-3 Section VI-5, first paragraph, last sentence. Change
"...a matter of gasketing". to "...a matter of gasketing
and welding".
- Page VI-5 Paragraph 7. Change "Reference 14 offers..." to
"References 14 and 36 offer..."
- Page VII-1 Section VI-1. Change "VI-1" to "VII-1". Second
paragraph, last sentence. Delete "two or three seconds".
- Page VII-5 First paragraph. Delete "(bunkers could replace the
shelter)".
- Page I-1-1 Add "Accustat - A fixed setting, non-adjustable
thermostat".
- Page I-1-4 Paragraph 4. Delete.
- Page I-1-5 Figure I-1-3, first note. Change to "Units to be used
with ducting may be supplied without attached supply and
return grilles". Second note. Change "thermostat" to
"thermostat or accustat".
- Page I-2-3 Add 36. Cain, Bruce L., EMI/RFI Gasketing for Tactical
Shelter Door Seam Applications. US Army Construction
Engineering Research Laboratory. To be published.

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